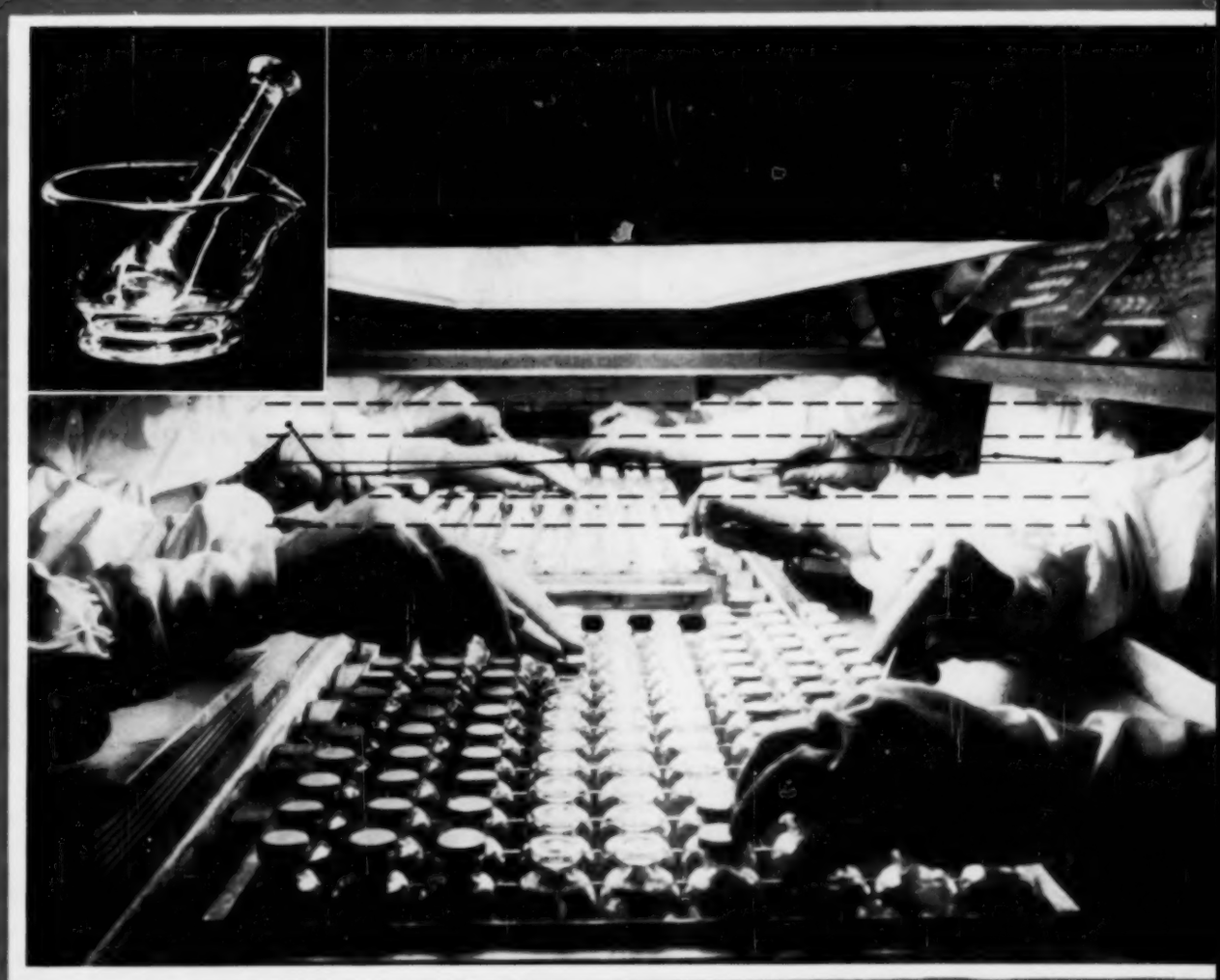
Industrial QUALITY CONTROL

SEPTEMBER, 1950 VOL. VII, NO. 2



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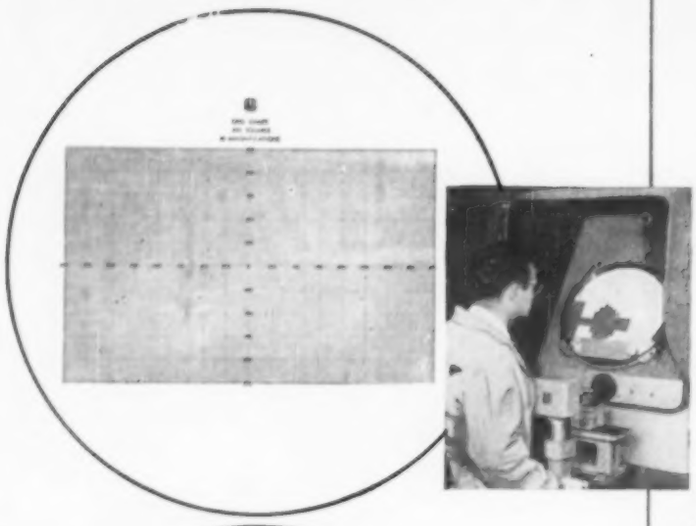

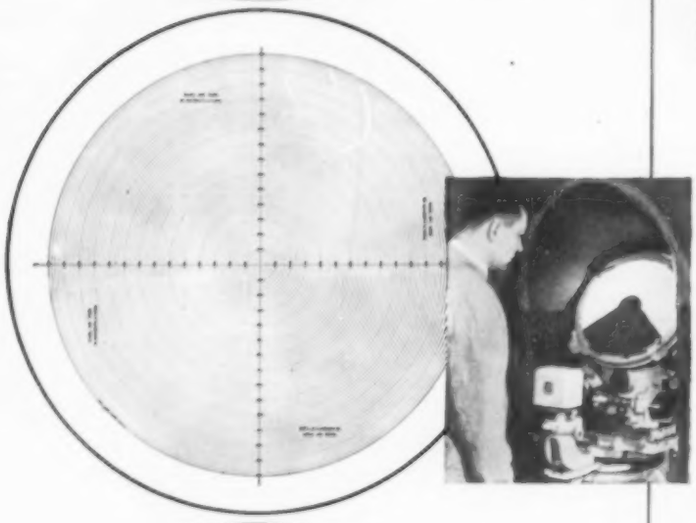

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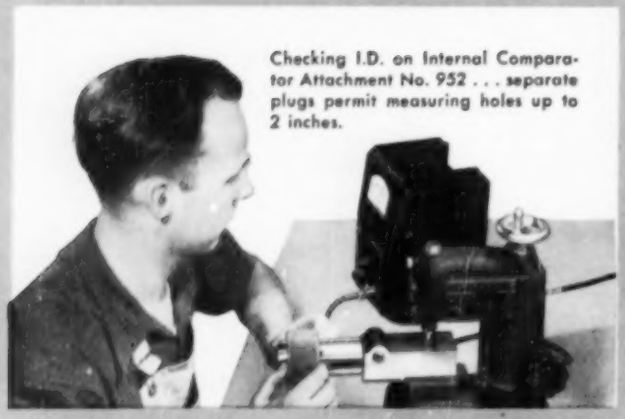

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A different type of exhibit will be one of the attractions. It will feature the products of industry from this region with emphasis placed on their quality characteristics. Shown also will be the statistical or other quality control methods, tools or other tangible things that brought about the desired customer quality in their products.

Plant visitations are planned for Friday, November 3rd.

The first technical session will begin at 2:15 P.M. on Friday and close at 3:45. Twin sessions are planned in two sets, the latter set to begin at 4:00 P.M. and close at 5:30. The subjects covered in three sessions will be mainly on technical theory, designed for engineers in almost any field or for those who are supervising or planning to supervise quality control programs. Mr. L. A. Seder, of the Gillette Safety Razor Company, will open the afternoon sessions with a half-hour talk on quality control and wage incentives.

A banquet, scheduled for 7:00 P.M. Friday, will have for its highlight an outstanding New England industrialist for the main speaker.

A well-known Military Ordnance representative will be the speaker at the luncheon on Saturday.

During Saturday, three sessions will run concurrently in a series of four for the day. The two in the morning will be from 9:15 to 10:30 and 10:45 to 12:00. The afternoon series will be held from 2:00 to 3:15 and 3:30 to 4:45.

Dr. J. M. Juran, Professor and Chairman, Department of Administrative Engineering, New York University, will conduct four of the Saturday sessions. His subject will be "The Management Problems of Quality Control."

Dorian Shainin, Chief Inspector, Hamilton Standard Division of United Aircraft Corporation, will conduct a like number of sessions on quality control principles.

For further information, write to

H. L. Hamilton
Hamilton Standard Div.
United Aircraft Corp.
East Hartford, Conn.

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INDUSTRIAL QUALITY CONTROL

Applications of Statistics to Drug Manufacture

ROLAND H. NOEL and MARTIN A. BRUMBAUGH

Bristol Laboratories

THIS subject is not intended to include the statistical analysis of data pertaining to the sales, credits and collections, profits, etc. of a concern manufacturing drugs. Rather the intention is to explain statistical methods which can be employed in production areas to improve quality of product and reduce cost of operation. The distinction between office statistics and factory statistics is not sophistry; it rests upon a shift from the economic to the engineering point of view; a shift from the time series, ratio, forecasting type of analysis to the frequency distribution, variability, probability type of analysis. This latter point of view and type of analysis commonly carries the title: Industrial Statistics or Statistical Quality Control. However, quality control is somewhat confusing in the drug industry because the function performed by the Control Department is only incidentally statistical, being principally the responsibility for the official status of all products whether or not they are subject to Food and Drug Administration supervision. Hence, Industrial Statistics is the preferred name for the procedures discussed in this paper.

The use of statistical analysis in drug manufacture can be explained most readily by examples. The examples which follow are applications of: (a) the frequency distribution; (b) the control chart; (c) a test of significance of differences of averages; (d) the Chi-square test; (e) variance analysis. Some of these techniques are applied to direct product and process analysis; others are applied to problems which arise in research, control, and development work. This distinction in origin of the problem will be apparent from the description of the case.

CASE I: PART A

Subject: Distribution of tablet thickness.

TABLE 1

Measured Thickness of 200 Tablets From Production Stream

Thickness (maximum diameter in inches, measured to nearest thousandth)	Number of Tablets
.238	2
.239	13
.240	32
.241	29
.242	18
.243	21
.244	20
.245	22
.246	22
.247	13
.248	3
.249	0
.250	1
.251	1
.252	0
.253	1
.254	0
.255	2
Total	200

Purpose: To set up a manufacturing specification.

Statistical Method: Analysis of a frequency distribution. (10)*

*Numbers in parentheses refer to titles listed in References at the end of this paper.

Data: Individual thickness of 200 tablets taken from the production stream as presented in Table 1.

Conclusion: Figure 1-A shows two peaks in the distribution, whereas a distribution of tablets made on a single machine or on a battery of machines all identically adjusted should produce a single humped symmetrical distribution. Specifications set up from this sample would be unreal. Presumably these tablets were made on several machines not set for the same weight, or on one machine which was adjusted during the time the sample was taken.

Recommendation: Discard the sample and plan for a new one free from the objectionable features of this one.

CASE I: PART B

Data: New sample of 200 tablets, Table 2, from the production stream after machines had been adjusted and synchronized.

Conclusion: This distribution, Figure 1-B, appeared to be a fair description of the variability of the machines, hence a specification was written from these data. The expected variability about the average of .242 inches is ± .004 inches, which would give expected limits of variation of .238 inches and .246 inches.

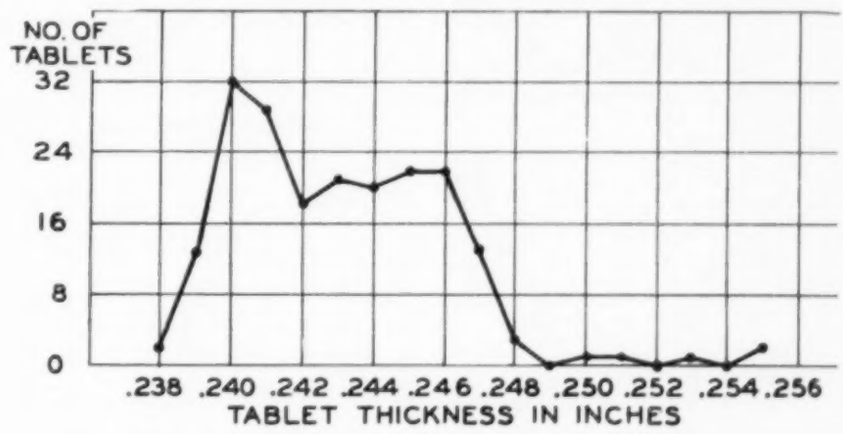

Figure 1A—**Frequency Graph for Data of Table 1**

TABLE 2

Measured Thickness of 200 Tablets From Production Stream After Machines Had Been Adjusted

Thickness (maximum diameter in inches, measured to nearest thousandth)	Number of Tablets
.238	1
.239	10
.240	20
.241	53
.242	71
.243	36
.244	7
.245	2
Total	200

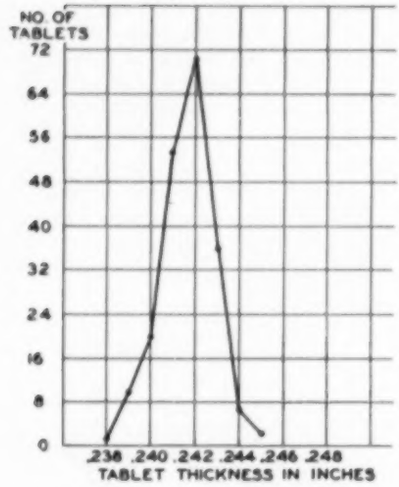

Figure 1B—**Frequency Graph for Data of Table 2**

Specification: Adjust the machines to a thickness of .242 inches and make no change as long as hourly samples of 5 tablets produce individual measurements between .238 and .246 inches, and the averages of the 5 tablets remain in control. (A control chart is presented in Case II.)

CASE II

Subject: Filling of isotonic solution in vials.

Purpose: To establish and maintain control of the volume filled during a production run.

Statistical Method: Control charts for averages and ranges of subgroups sampled from the production stream at regular intervals. (1) (2)

Data: (As originally collected and analyzed.) Table 3.

Analysis: A control chart is a running record of the level at which the material is being produced (in this

TABLE 3

Record of Filling Isotonic Solution with Averages and Ranges Computed

Lot No. 500 Machine: Automatic Label Fill: 30 cc.
Date: 5/12/47 4 Needle Filler Required Fill: 31 cc.

(Measurements accurate to ¼ cc.)

Needle #1	Samples of 3			$\bar{X}$	R	Needle #3	Samples of 3			$\bar{X}$	R
1st hr.	31.0	31.0	31.0	31.0	.0	1st hr.	31.5	31.5	31.5	31.5	.0
2nd hr.	31.0	31.0	31.25	31.1	.25	2nd hr.	31.5	31.5	31.5	31.5	.0
3rd hr.	31.0	31.0	31.0	31.0	.0	3rd hr.	31.5	31.5	31.5	31.5	.0
4th hr.	30.5	31.5	31.5	31.2	1.00	4th hr.	31.5	31.5	31.5	31.5	.0
5th hr.	31.5	31.5	31.5	31.5	.0	5th hr.	31.75	32.0	31.75	31.8	.25
Needle #2	**Samples of 3**			$\bar{X}$	R	**Needle #4**	**Samples of 3**			$\bar{X}$	R
1st hr.	31.0	31.5	31.5	31.3	.50	1st hr.	31.5	31.5	31.5	31.5	.0
2nd hr.	31.0	31.0	31.0	31.0	.0	2nd hr.	31.75	31.75	31.75	31.8	.0
3rd hr.	30.0	31.0	31.5	30.8	1.50	3rd hr.	31.75	31.75	31.75	31.8	.0
4th hr.	31.5	31.5	31.5	31.5	.0	4th hr.	31.75	31.75	31.75	31.8	.0
5th hr.	31.0	31.0	31.0	31.0	.0	5th hr.	31.75	31.75	31.75	31.8	.0

$$\bar{\bar{X}} = \frac{\Sigma \bar{X}}{n} = \frac{627.8}{20} = 31.39 \qquad \bar{R} = \frac{\Sigma R}{n} = \frac{3.50}{20} = .175$$

Control Limits for Averages

$\bar{\bar{X}} \pm A_2 \bar{R}$ where A_2 is a constant such that $\pm A_2 \bar{R}$ will include practically all of the chance variability of averages of three individuals.

$31.39 \pm (1.023)(.175)$ gives:

Upper Control Limit = 31.57
Lower Control Limit = 31.21

Control Limits for Ranges

Upper Control Limit = $D_4 \bar{R}$
Lower Control Limit = $D_3 \bar{R}$
where D_3 and D_4 are constants such that $D_3\bar{R}$ to $D_4\bar{R}$ will include practically all of the chance variability of ranges of three individuals.

$D_4 \bar{R} = (2.574)(.175) = .450$
$D_3 \bar{R} = (0)(.175) = 0$

Values of the constants A_2, D_3, and D_4 are taken from Reference (1), page 39, or Reference (2), page 50.

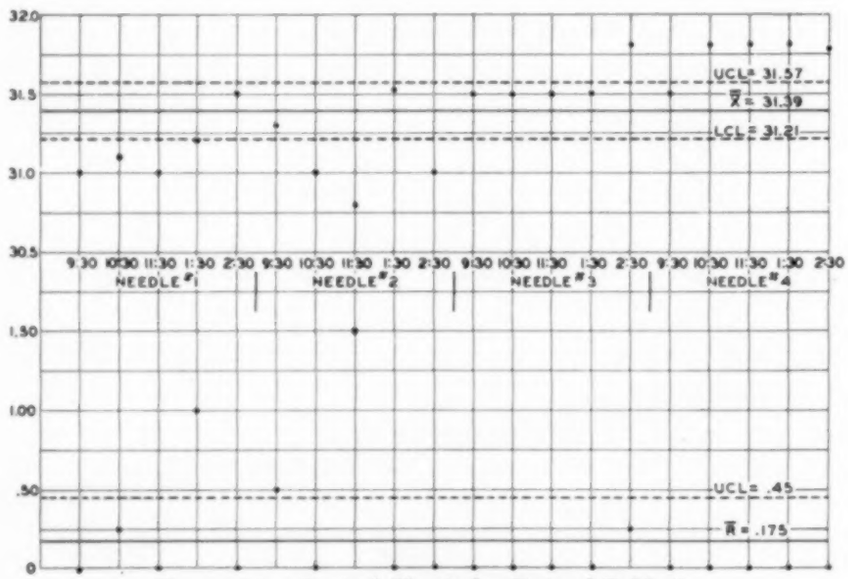

Figure 2A—**Control Charts for Data of Table 3**

TABLE 4

Sup-Groups of Four Across Needles With Averages and Ranges Computed

Hour	Needle No. 1	2	3	4	$\bar{X}$	R
5/13						
8:15	31.25	31.	31.25	31.5	31.25	.5
9:25	31.	31.	31.5	31.5	31.25	.5
10:15	31.	31.5	31.25	31.5	31.31	.5
11:30	31.	31.25	31.5	31.5	31.31	.5
1:10	31.25	31.	31.5	31.75	31.38	.75
2:00	31.25	31.	31.5	31.5	31.31	.5
2:50	31.	30.5	31.5	31.75	31.19	1.25
3:50	31.	31.	31.5	31.5	31.25	.5
5/14						
8:15	31.	31.25	31.5	31.5	31.31	.5
9:05	30.5	31.5	31.25	31.75	31.25	1.25
10:10	31.5	31.25	31.5	31.75	31.50	.5
11:00	31.25	31.5	31.5	31.75	31.50	.5
12:40	31.5	31.	31.75	31.75	31.50	.75
2:05	31.5	31.	32.	31.5	31.50	1.00
3:10	31.	31.	31.5	31.75	31.31	.75

$\bar{\bar{X}} = 31.34$; $\bar{R} = .683$

Control Limits for Averages

$\bar{\bar{X}} \pm A_2 \bar{R} = 31.34 \pm (.729)(.683)$
Upper Control Limit = 31.84
Lower Control Limit = 30.84

Control Limits for Ranges

$D_4 \bar{R} = (2.282)(.683) = 1.56$
$D_3 \bar{R} = (0)(.683) = 0.$

case filled) with limits of chance variability indicated on the chart. In Figure 2-A, charts for averages of sub-groups and ranges of sub-groups are presented. Averages of the fill of sub-groups of 3 vials filled through the same discharge needle are plotted on the average chart and the average of 20 such sub-groups (31.39) is indicated on the chart. The limits of chance variability of these averages are also indicated, the upper control limit at 31.57 and the lower control limit at 31.21. If any of the average points fall outside these limit lines, some change in the filling operation has occurred and should be investigated immediately. (1) (2)

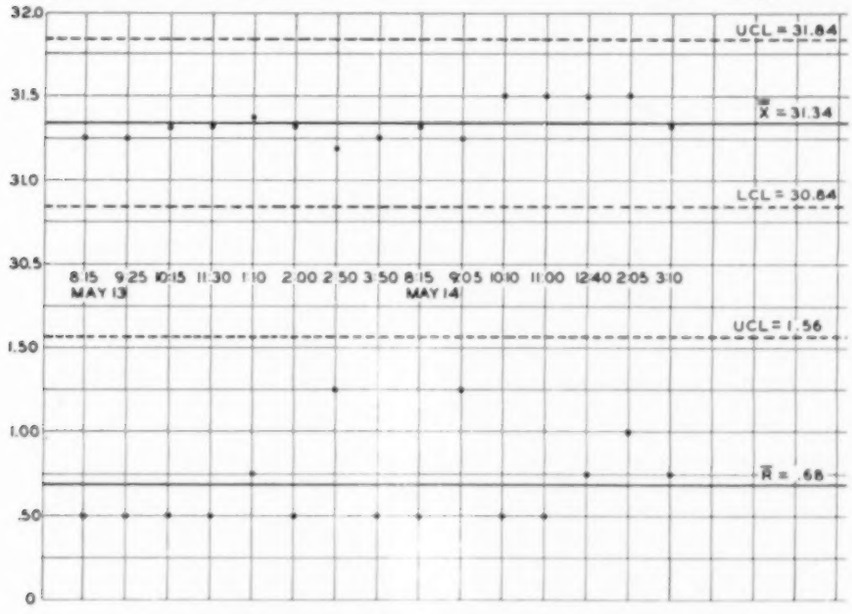

Figure 2B—**Control Charts for Data of Table 4**

The range chart serves a similar purpose in evaluating the variability within sub-groups. The range is the difference between the greatest and smallest values in the sub-group. These twenty ranges are plotted and the average range ($\bar{R}$) and upper control limit are indicated on the chart. Here also, points out of control should be investigated.

Even a cursory glance discloses something amiss in these two charts. For the first needle, four points on the average chart and one point on the range chart are out of control. For the second needle, three points on the average chart and two on the range chart are out of control. For the third needle, one point on the average chart is out of control. For the fourth needle, four points on the average chart are out of control.

An equally casual survey shows that the fill of these vials is fairly regular at about the proper level. Usually at this point someone raises the question: "What good are control charts?" The answer lies in the exercise of some engineering judgment, otherwise known as common sense. There are two major faults reflected in these charts. Three sources of variability are present in the data: (a) variability from hour to hour; (b) variability from needle to needle; (c) variability between vials filled at the same time through the same needle. One of these, (c), is measured by the range chart, the other two are in the averages chart and it is evident that the needles are filling at different levels. The variability of triplicates from the same needle is small, being zero in 15 of the 20 samples. The control chart system is set up so that the consistency of two causes of variability can be checked. In this case the variability between needles at the same time can be checked with the variability of replicates from the same needle, or the variability of the process over a period of time, but the control charts of Figure 2 are an attempt to check the variability of triplicates from the same needle against combined time variability and variability between needles. In this case the replicates have mainly zero variability; hence it is better to combine this variability with the variability between needles and check this combined variability against that of the process over a

period of time.(11)

The second major fault lies in the fact that the time variable is consecutive within needles but not for the process as a whole. Shift of the variability between needles to the range chart will automatically correct this fault.

The new system involved taking one vial from each needle hourly, and computing the average and range of this sub-group of four, as indicated in Table 4. The control charts are presented in Figure 2-B.

Conclusion: The process is in control during the two day run (average chart). The variation between needles is in control (range chart).

The variability and average are consistent with the label fill. The test consists in finding the estimated variability of fill of individual vials by dividing $\overline{R}$ by a constant provided by previous statistical work. The ratio between the average of ranges of sub-groups of fixed size and the standard deviation of the universe of measurements from which the samples are drawn is a constant designated by the symbol d_2. Thus $\sigma' = \overline{R}/d_2$, or .683/2.059 = .33. But a spread of $\pm$ 3σ' from the average will include nearly all of the chance variability of individuals. (1) This computation shows that practically all of these vials should be filled within a range of 1 cc. on either side of the average, i.e., in the range 30.34 to 32.34 cc.

Recommendations: Maintain these control charts on future production lots by use of the same averages and limits computed for this initial run. As long as no points fall outside of the control limits the fill will be satisfactory.

If more expensive material is to be filled on this filling machine, the filling heads can be adjusted so as to reduce the variability of the range chart and thus permit an overfill less than 4½% of the label fill, i.e., 31.34/30 = 1.044.

CASE III

Subject: Assay of sterile broth from penicillin fermenters.

Purpose: To determine whether a certain type of filtration will cause a significant change in the units per ml. as measured by the assay.

Statistical Method: Test of significance of the differences between assays of samples identically prepared except for one filtration step. (4) (5) (7) (8) (10)

TABLE 5

Record of ou /ml. of Broth Samples From 22 Penicillin Fermenters With and Without Filtration, With Computations for Testing the Significance of Differences by the Two Filtration Methods

(Data Coded by Introducing a Constant Multiplier)

X_1 With Filtration	X_2 Without Filtration	$(X_1 - X_2)$ D	$(X_1 - X_2)^2$ D^2
917	936	— 19	361
609	705	— 96	9216
758	705	+ 53	2809
675	718	— 43	1849
538	620	— 82	6724
626	504	+122	14884
776	666	+110	12100
740	693	+ 47	2209
528	625	— 97	9409
835	808	+ 27	729
646	673	— 27	729
633	661	— 28	784
760	776	— 16	256
380	396	— 16	256
574	562	+ 12	144
655	768	—113	12769
736	855	—119	14161
707	665	+ 42	1764
616	654	— 38	1444
614	583	+ 31	961
757	695	+ 62	3844
682	708	— 26	676
		—710	98078
		+506	
		22) —204	
		$\overline{D}$ = —9.3	

For Test of Significance:

$$t = \frac{|0 - \overline{D}|}{\sqrt{\frac{\Sigma D^2 - \frac{(\Sigma D)^2}{n}}{(n-1)\,n}}} = \frac{9.3}{\sqrt{\frac{98078 - \frac{(-204)^2}{22}}{(21)(22)}}} = \frac{9.3}{14.4} = .65$$

Data: Assay values of broths from 22 fermenters as shown in Table 5.

Analysis: The differences between pairs of assays on the same broth should be randomly distributed with average zero for a large number of samples, if the filtration has no effect. The result is an average difference of –9.3 for 22 samples. Is this difference evidence that the assays are higher without filtration or might the value, –9.3, occur rather frequently as a chance variation from the expected zero with 22 samples? This question is answered by carrying out the "t" test outlined at the bottom of Table 5. A value of t as large as 2.08 would occur once in twenty such analyses of 22 samples purely by chance. (4) (5) (7) (8) (10) Hence a small value, .65, would occur very frequently by chance.

Conclusion: In making the "t" test, the initial hypothesis is set up that the two sets of samples are from the same universe, i.e., that the filtration does not affect the assay result. If the t value is one that is likely to occur as a result of variations due to small sample size, then there is no reason to reject the hypothesis; the element which is different in the two sets of samples is presumed to have no effect. If, on the other hand, the value of t obtained is one which would occur infrequently as a chance sampling variation, the hypothesis of common origin is rejected and the element of difference is presumed to have an

TABLE 6

Fermenters Harvested That Were Contaminated and Not Contaminated by Technicians and Operators

Samples Taken by	Number of Tanks Harvested For Which Samples Were				Total	
	Contaminated		Not Contaminated			
Technicians	17	(27)	157	(147)	174	(174)
Operators	56	(46)	240	(250)	296	(296)
Total	73	(73)	397	(397)	470	(470)

Computation of χ^2:

$$(26.5-17.0)^2/26.5 = 3.41$$
$$(56.0-46.5)^2/46.5 = 1.94$$
$$(157.0-147.5)^2/147.5 = 0.61$$
$$(249.5-240.0)^2/249.5 = 0.36$$
$$\chi^2 = 6.32$$

For P = .02, χ^2 = 5.41; for P = .01, χ^2 = 6.64

effect. In this case, the hypothesis is accepted and filtration is presumed to have a negligible effect. (4) (5) (7) (8) (10)

Recommendation: Eliminate the filtration step which increased the cost of the assay, increased the preparation time of the broth, but produced no significant change in the resulting assay value.

CASE IV

Subject: Contamination of samples from penicillin fermenters.

Purpose: To determine whether trained technicians can take samples with lower contamination rates than operators.

Statistical Method: Analysis of a 2 x 2 contingency table using the χ^2 test for significance of differences in frequency of occurrence of contaminated samples. (4) (7) (8) (10)

Data: Record of the number of fermenters harvested during a period of more than two months and the number of samples presumed to be contaminated because of extreme variation between in-process and harvest assay results. The data appear in Table 6.

Anaylsis: The first step is to find what the frequencies in each of the four cells of the Table would be if contamination were unrelated to sampler. These are obtained by dividing the product of the respective column and row totals by the total of the Table, e.g., 27 = (73x174) / 470. All of the independence values appear in the Table with parentheses. However, there is a grouping correction of ½ unit which must be introduced so as to decrease by ½ unit all independence frequencies which exceed the corresponding actual frequencies and to increase by ½ unit all independence frequencies which are less than the corresponding actual frequencies.

Chi-square is computed in the lower part of the Table by squaring the individual differences between the actual and independence frequencies and dividing by the corresponding independence frequency. The sum of these quotients is the value of Chi-square. The larger this value, the smaller the chance that the diffferences between actual and independence frequencies are random sampling variations.

Conclusion: In this case the value, 6.32, would occur less than twice in one hundred trials due to sampling variation alone. (4) (7) (8) (10) The hypothesis of chance occurrence should be rejected. The technicians have a lower sample contamination rate.

Recommendation: It would seem that all samples should be taken by technicians. Actually a preliminary step was taken. These data were reported to both technicians and operators with a request for improvement. In another month the difference had disappeared and by continuing to report data for another three months, the contamination rate of both groups had dropped to less than one percent. The record is being maintained currently.

CASE V

Subject: Discovery of sources of laboratory variability of a chemical assay through analysis of a designed experiment.

Purpose: To find the amount of variability introduced into the assay results through lack of precision in the analytical technique.

Statistical Method: Analysis of variance employed with a design involving three independent factors with duplicate determinations. (4) (5) (6) (8) (10)

Data: The variables were: (a) four analysts; (b) two successive days; (c) two independent samples, i.e., material at two different potencies. The material was prepared as follows: (see Table 7). Sample 1 was divided into 16 aliquots. Each of these was given a different serial or code number and 8 of the coded subsamples were refrigerated for Day 2. The other 8 were submitted at different times during Day 1, two each to Analysts A, B, C, and D. Thus Analyst A found these two samples to have potencies of 1053 and 1053, but Analyst B found his two to have potencies of 1233 and 1217, and so on. The sub-samples of Sample 2 were prepared and distributed similarly. Analyst A, for example, found the potency of Sample 2 to be 1305 and 1336 on the first day, and 1415 and 1415 on the second day.

The experiment is set up so that in comparing Analysts, eight independent observations are available from which to judge the work of each Analyst. Likewise 16 independent observations for each Sample are available from which to judge whether the potencies of the two samples were alike or different. Also, 16 independent observations for each Day are available from which to judge whether refrigeration for 24 hours affected the potency. Finally, two independent observations are available in each of four blocks from which to judge the reproducibility of results by the Analysts without regard to the Day-to-Day or Sample-to-Sample variability.

Analysis: The experiment is designed for the use of analysis of variance technique. The procedure used will lead to separate determination of the variability attributable to each of the three variables, will allocate separately any existing inter-relations among the variables, and will separate the variability due to duplicates from that due to the independent variables.

The arithmetic required to accomplish these objectives is well standardized and readily available. (4) The first step is to prepare three

TABLE 7—Analysis of Variance: Three Factors with Replication (all data coded)

Analyst A				Analyst B				Analyst C				Analyst D			
Sample 1		Sample 2		Sample 1		Sample 2		Sample 1		Sample 2		Sample 1		Sample 2	
Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
1053	1195	1305	1415	1233	944	1417	1349	1157	1163	1474	1163	1248	1209	1311	1319
1053	1258	1336	1415	1217	1142	1356	1158	1062	1138	1348	834	1147	1099	1358	1311

Summary of Variance

Source	Sums of Squares	D. of F.	Mean Squares	Remarks
Analysts	38305	3	12768	
Samples	203363	1	203363	
Days	28981	1	28981	
Interactions:				
A x S	25374	3	8458	
A x D	127534	3	42511	
S x D	26392	1	26392	
A x S x D	81049	3	27016	
Residual	121466	16	7592	
Total	652464	31		

*Significant at 5% probability level

2-variable tables. The table for Analysts and Samples is obtained by summing for Days and Duplicates, and would appear as follows.

	Analyst A	Analyst B	Analyst C	Analyst D	Total
Sample 1	4559	4536	4520	4703	18318
Sample 2	5471	5280	4819	5299	20869
Total	10030	9816	9339	10002	39187

Four sets of sums of squares are computed from this table.

1. Square the individual entries, sum, and divide by the number of original potencies present in each entry:
   $(4559^2 + 5471^2 + \ldots\ldots\ldots + 5299^2)/4 = 48255197$
2. Square the column totals, sum, and divide by the number of original potencies represented:
   $(10030^2 + \ldots\ldots + 10002^2)/8 = 48026460$
3. Square the row totals, sum, and divide by the number of original potencies represented:
   $(18318^2 + 20869^2)/16 = 48191518$
4. Square the grand total, and divide by the total number of original potencies:
   $39187^2/32 = 47988155$

The "sum of squares" for Analysts in the Summary of Variance Table (Table 7) is obtained by subtracting (4) from (2), i.e., 48026460 — 47988155 = 38305

For samples it is (3) — (4), i.e., 48191518 — 47988155 = 203363.

The A x S interaction is (1) + (4) — (2) — (3), i.e., 48255197 + 47988155 — 48026460 — 48191518 = 25374

The remaining entries in the Summary of Variance Table are obtained in similar fashion from the other two 2-way tables and from the 3-way table. (4)

The column headed Degrees of Freedom in the Summary of Variance Table contains the figures by which the Sums of Squares are divided to obtain the Mean Squares. There are four Analysts in the design, hence one less than that, or three degrees of freedom, for analysts. There are two samples and two Days, hence there is one degree of freedom for each variable. The concept of degrees of freedom is explained in references (7) (8) and (10). The number of degrees of freedom for each first order interaction is the product of the degrees of freedom of the main effects involved. The number of degrees of freedom of the second order interaction, A x S x D, is the product of the degrees of freedom of the three main effects. Since there are two potencies in each block of the original table, one degree of freedom is assigned to each block so that there are 16 degrees of freedom for the residual. The total number of degrees of freedom is one less than the number of entries in the original table.

The interpretation of results is made from the Mean Squares column. The reading of the column is from the bottom toward the top. The residual mean square, 7592, is the variance found in the duplicates by the same Analyst, of the same Sample, on the same Day. In other words, this is a measure of the reproducibility of these analysts. If no other mean square exceeded this one, it would be proper to conclude that the residual expressed the only source of variability present. If other mean squares do exceed the residual mean square, the question that must be investigated is whether the excess is an amount which might be expected to occur frequently merely as a result of sampling variability, or whether it is sufficiently large to warrant rejection of the hypothesis of chance causation in favor of a conclusion that an additional cause of variability is present. In comparing the second order interaction mean square with the residual mean square a judgment of this sort must be made. The argument follows these lines: make the initial hypothesis that 27016 differs from 7592 merely because of sampling variability. Information concerning the hypothesis is obtained by using the F-Test. This consists in dividing the interaction mean square by the residual mean

TABLE 8

Analysis of Variance by Analysts: Two Factors with Replication

Analyst A

Source	Sums of Squares	D. of F.	Mean Squares
Samples	103968	1	103968***
Days	35911	1	35911**
Interaction:			
S x D	3121	1	3121
Residual	2465	4	616
Total	145465	7	

Analyst B

Source	Sums of Squares	D. of F.	Squares Mean
Samples	69192	1	69192*
Days	49612	1	49612
Interaction:			
S x D	1201	1	1201
Residual	39831	4	9958
Total	159836	7	

Analyst C

Source	Sums of Squares	D. of F.	Mean Squares
Samples	11175	1	11175
Days	69006	1	69006
Interaction:			
S x D	102332	1	102832
Residual	66883	4	16721
Total	249896	7	

Analyst D

Source	Sums of Squares	D. of F.	Mean Squares
Samples	44402	1	44402**
Days	1985	1	1985
Interaction:			
S x D	288	1	288
Residual	12287	4	3072
Total	58962	7	

* Significant at 5% probability level

** Significant at 1% probability level

*** Significant at .1% probability level

square and consulting prepared tables (4) (5) (7) (8) and (10) of the F ratio to discover with what probability the computed ratio would occur as a chance event in dealing with small samples. The star in the Remarks column is the usual notation to indicate that a ratio of 3.56 would occur less than once in twenty trials as a chance event. The initial hypothesis is therefore rejected because it appears to be more rational to assume that for some reason one or more of the Analysts have not acted like the others in handling the two Samples and that the same is true of their analyses on the two Days. In the usual terminology, there is a significant second order interaction in the problem. Until this interaction has been investigated there is no point in attempting to evaluate the remaining mean squares in the table.

TABLE 9—**Precision of Analysts**

Item	Analyst A	Analyst B	Analyst C	Analyst D
σ_o^2	616.	9958.	16721.	3072.
σ_o	24.8	99.8	129.7	55.4
$2.78\sigma_o$	68.9	277.4	360.6	154.0
Relative variability	$\frac{68.9}{1254}$ = ± 5.5%	$\frac{277.4}{1227}$ = ± 22.6%	$\frac{360.6}{1167}$ = ± 30.9%	$\frac{154.0}{1250}$ = ± 12.3%

The purpose of the investigation is to catalog the variability of the analysts, hence the proper method of discovering the cause of the interaction is to carry out a 2-variable variance analysis for each analyst separately. The results of computations similar to those already shown are set forth in Table 8. For Analyst A the F-Test shows that the S x D interaction was not significant but the day-to-day main effect was significant at the 1% probability level and the sample-to-sample main effect was significant at the .1% probability level. This means that Analyst A found the potencies of the two samples to be different, but it also means that he found a difference in potency of the samples from day to day. Analyst B's results are questionable because of the very large value of the residual mean squares, but he did find a significant difference in potency of the two samples at the 5% probability level. The residual mean square for Analyst C is so large that he cannot detect any significant difference in his samples. Analyst D does not have precision of duplicates equal to that of Analyst A, but in general his work is the best of the four. The interaction term is negligible, the day-to-day variability is small and the difference in potency of the two samples is evident.

The cause of the second order interaction is apparent. The A x S interaction arose primarily because Analyst C could not detect the difference in potency of the samples whereas the others could. The A and D interaction arose because Analyst A found a day-to-day difference, whereas Analyst D did not. These combinations would produce a second order interaction, but there is additional reason for it in the indiscriminately erratic work of Analysts B and C.

The crux of the whole matter lies in reducing the variability of duplicates, the residual mean square of the individual Analysts. As a basis for action Table 9 was prepared. It shows for each Analyst the residual variance taken from Table 8, the standard deviation which is the square root of the variance, the 95% confidence interval, or the band within which 95% of each Analyst's results could be expected to fall if a large number of assays were performed on the same day on material of the potency of these samples, and the relative variability of each Analyst. The figure 2.78 is taken from the "t" Table for four degrees of freedom. (4) (5) (7) (8) (10).

Conclusion: The experiment shows that Analyst A is making some error in technique from day to day. Analysts B and C are doing poor work. Their cases require investigation. Analyst D is quite capable of doing this work, but appears to be careless.

Recommendation: That Analyst A's work be investigated by a supervisor to discover the cause of the day-to-day variation (the error was

quickly found to be in the use of the standard test solution); that Analysts B and C be removed from this work until they have been completely retrained; that Analyst D be commended for his ability in performing the test, but that his carelessness be pointed out; that the test be repeated after the prior recommendations have been carried out; and that control charts be introduced to give each Analyst a running record of the precision of his work.

SUMMARY

These five cases have been selected solely for the purpose of demonstrating the broad scope of manufacturing problems in the drug industry to which statistical methods can be applied. The examples are not in themselves important, although considerable improvement in operations has resulted from this statistical work.

There is scarcely any limit to the scope of problems to which the statistical method is applicable. Work has been done in sampling of incoming materials, sampling for the Control Department, design of experiments in Research and Development, the use of sequential analysis in penicillin strain work, and the routine control of processes and products.

One characteristic of statistical work in the drug industry should be mentioned. There are usually so many sources of variability involved in any problem that the more elementary techniques, ordinarily applicable in mechanical industries, are inadequate. For that reason, some basic statistical knowledge is indispensable to successful application of these techniques in drug manufacturing. This circumstance need not be a deterrent, because the requisite knowledge is readily available from a number of sources.

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Statistical Quality Control In The Manufacture of Pharmaceuticals*

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PURPOSE

There have been many attempts to define briefly the phrase "quality control by statistical methods." Most brief definitions do not indicate much more information than the phrase itself, and as the literature on the industrial applications of statistical methodology becomes more voluminous, it is increasingly apparent that a definition that will be broad enough to include the entire area of application and at the same time specific enough to give adequate meaning, has little chance of ever being written.

The absence of an adequate definition for a subject, however, does not preclude a description of some of its salient features and a discussion of what it can and has accomplished when applied to industrial problems. Therefore, the purpose of this paper is to present some basic concepts of statistical quality control and to enumerate some of the things that can be expected from it when it is applied in the right proportion with other technology to some of the problems of the pharmaceutical industry, and to give illustrative examples as space permits.

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SQC AND PHARMACEUTICAL PRACTICE

The fundamental concept of statistical quality control and the fundamental concept, "good pharmaceutical practice," are one and the same thing. It is the basic idea of building quality into a product by maintaining a rigid set of manufacturing controls on every step of the production process. Our industry has developed this idea by employing manufacturing control systems that, by and large, are far more comprehensive than the systems utilized by most other industries. In fact, the basic philosophy of statistical quality control is so like that of pharmaceutical quality control that it is surprising that our industry was not the first to adopt it.

To build quality into a product may well be the sincere desire of every worker in the plant but how to accomplish this economically is still another matter. It must be obvious that one of the necessary tools for accomplishing this feat is one which will provide a factual basis for evaluating a production process and which will enable specifications to be set in a scientific manner. Statistical quality control is a tool which meets these requirements. It does so by applying the relatively simple mathematics of nature to problems in which there is a strong tendency toward arbitrary decisions and thus it eliminates the errors arising from guess work.

Statistical quality control recognizes one principle that is at times difficult for the pharmaceutical manufacturer to digest. This is the principle of variation. Statistical quality control accepts the fact that no two manufactured products are exactly alike regardless of the refinements made in the production process. It also recognizes that there is usually a large number of causes which contribute to the total variation between individual units of the same product, but unlike other methods, it provides factual evidence which will discriminate between those variations that can be identified with an assignable cause and those which are naturally inherent in the specific process. In addition, the fundamental techniques of the method are practical enough to be applied routinely by operating personnel without any excessive additional supervision.

The common practice in setting quality levels in the pharmaceutical industry seems to follow a pattern of establishing, as a minimum, the standards of the official compendia and then adding a certain "plus value" which represents the quality standards of the individual management. There is nothing wrong with such a practice but it should be pointed out that the administration of this policy is beset with pitfalls which must be avoided if the enterprise is to be successful. There is always the danger of allowing such a practice to give birth to non-competitive quality standards. This can happen in one of two ways both of which produce equally serious consequences. First, quality levels can be raised to heights that will quickly destroy the competitive cost structure. Secondly, they can be lowered to levels that will involve the producer in excessive risks from both the market and legal standpoints. Clearly then, some middle of the road policy must be adopted and this is no easy task for the road is, most generally, a narrow one and expert driving will be required.

HOW SQC CAN HELP

What can statistical quality control do to help solve this problem? Before this question is answered, it should be emphasized that the method has been referred to elsewhere in this paper as only a tool and it should be understood that it is not a panacea for all of the problems of the industry. Nevertheless, some of the things we can expect of it in helping to solve the problem at hand can be enumerated.

First of all, we can expect its use to effect economies in the use of raw materials by providing a basis for more realistic specifications for purchased goods and better scientific sampling methods for incoming materials. Economies in raw materials are also indirectly effected through a more efficient utilization of them as a result of process control.

Secondly, it can be expected that economies in the use of both man and machine power will be realized. This is usually accomplished by an increase in output per man-hour and per machine-hour, which is the net result of putting man power to work on the investigation of variations that are identified with some assignable cause rather than wasting man power in a guessing game on where the trouble may be. It also stems from a reduction in the number of reoperations required.

Third, statistical quality control can be expected to reduce inspection costs. This is accomplished by substituting process inspection for product inspection and utilizing scientific sampling plans for check inspection of the final product.

Fourth, in-process control by this method can be expected to reduce the production of rejects.

Fifth, the acceptance of this method of in-process control improves the relationship between the production and control groups because the method provides objective records which supplant subjective opinions.

Sixth, the control department has a charted record, which carefully read, provides a quick history of the progress of a particular lot through the production process. In case of any doubtful results in the official tests, appeal to the chart allows the control department to evaluate the seriousness of such results and make decisions concerning the lot which are more meaningful than the usual arbitrary rejection or acceptance. Production quickly learns that the chart is its best friend and not an additional club of the control department.

Finally, management can be assured of an improved quality level and a more homogeneous product produced at lower costs. Also, the method will provide management with discriminating information concerning quality levels which they otherwise seldom get.

SETTING REALISTIC SPECIFICATIONS BY STATISTICAL ANALYSIS

So much for the point of view and a broad outline of the features of statistical quality control. At this point, let us shift from the general to the particular by considering in some detail an application of these principles to a manufacturing process.

Consider the problem of controlling the filling of a relatively viscous injectable suspension in multiple dose containers. The specification reads that ten separate 1 cc. injections shall be available from a ten dose vial. The overall problem is simply how much must be put into the vial to meet this specification. It has already been intimated that there are those who would recommend putting in an *adequate* amount. This is highly laudable but not feasible under today's condition of competition. The proper procedure

is to find the *right* amount to fill into these vials.

The first step is to catalog the sources of variability in both the filling and the testing. In this case they are:

1) The residual amount of material in the syringe and the variability between syringes—syringe holdup.
2) The residual amount of material which cannot be withdrawn from the vial and the variability in this amount from vial to vial—vial holdup.
3) The specific gravity of the suspension and its variability from lot to lot.
4) The variability of the filling equipment.

The average value for each of these contributing sources of variability and a measure of the dispersion about it can be easily and quickly obtained. This is done by making several measurements (preferably 20 or more) of the syringe holdup, vial holdup, etc. and calculating the average value for each. The measure of dispersion is obtained by calculating the standard deviation (σ') which is given by

$$\sigma' = \sqrt{\frac{\Sigma X^2 - (\Sigma X)^2/N}{N-1}}$$

where X is equal to an individual measurement, Σ denotes summation, and N is equal to the number of measurements in the series. The square of this value is known as the variance.

The averages and standard deviations are shown in Table I.

TABLE I

Source	Average	Standard Deviation
Syringe holdup (1 cc. dose)	0.150 gm.	0.0052 gm. $= \sigma_s$
Vial holdup (10 cc. vial)	0.506 gm.	0.0430 gm. $= \sigma_v$
Specific gravity	1.007	Nil
Variation in filling equipment	10.00 cc.	0.034 gm. $= \sigma_F$

The variability in specific gravity from lot to lot was small and well within the variability associated with several determinations on the same lot of material and, therefore, its contribution was insignificant. Having these values available, it is now possible to calculate what the filling figure should be. It was desired that this be in terms of weight, and thus the filling figure is derived from the following formula:

$$(10.0)\ (1.007) + 0.506 + (10.0)\ (0.150) \pm 3\sqrt{\sigma^2_s + \sigma^2_v + \sigma^2_F}.$$

This formula converts 10 cc. to grams by multiplying by the average specific gravity and adds the average vial holdup in grams, the average syringe holdup in grams, and finally takes into account three times the square root of the sum of the contributing variances in grams, viz:

$$(10.0)\ (1.007) + 0.506 + (10.0)\ (0.150) \pm 3\sqrt{0.0052^2 + 0.043^2 + 0.034^2} = \begin{cases} 12.241 \\ 11.911. \end{cases}$$

The reason for including three times the square root of the sum of the variances can be explained best by the diagram shown in Figure 1. In terms of weight, 10.07 grams must be averagely obtained for ten 1 cc. injections. The vial holdup will be averagely 0.506 gm. and the holdup in the syringe is averagely 0.15 gm./cc. or 1.5 gm. for 10 cc. These total an amount equal to 12.076 gm. The individual values, however, which made up the respective averages vary about them according to the normal or Gaussian curve and it is possible to calculate a value about each of these separate averages which will include about 99.73% of the individual values making up the average. This is done by adding and subtracting from each average an amount equal to three times the standard deviation for the respective measurements. However, the distribution of the sum of N normal and independent variables each of normal form also produces a normal or Gaussian curve whose standard deviation is equal to the square root of the sum of the individual standard deviations squared (variances). In this example, the square root of the sum of the variances was 0.055 gm. This is the total standard deviation (σ_t) and $3\sigma_t = 0.165$ gm. (Figure 1A).

When the filling machines are set to deliver an average of 12.241 gms. (Figure 1B), one can expect about 99.73% of the vials to contain between 12.076 grams and 12.406 grams, respectively. That is, there is a chance that approximately three out of a thousand vials will contain a quantity outside of these ranges; and further since the curve is symmetrical, the chances are equal (0.00135) that a vial will exceed the upper or lower limit, respectively. Thus, the probability of distributing into the trade an underfilled vial is 0.00135.

PROCESS CONTROL THROUGH SQC CHARTS

The analysis of the variables affecting this particular filling prob-

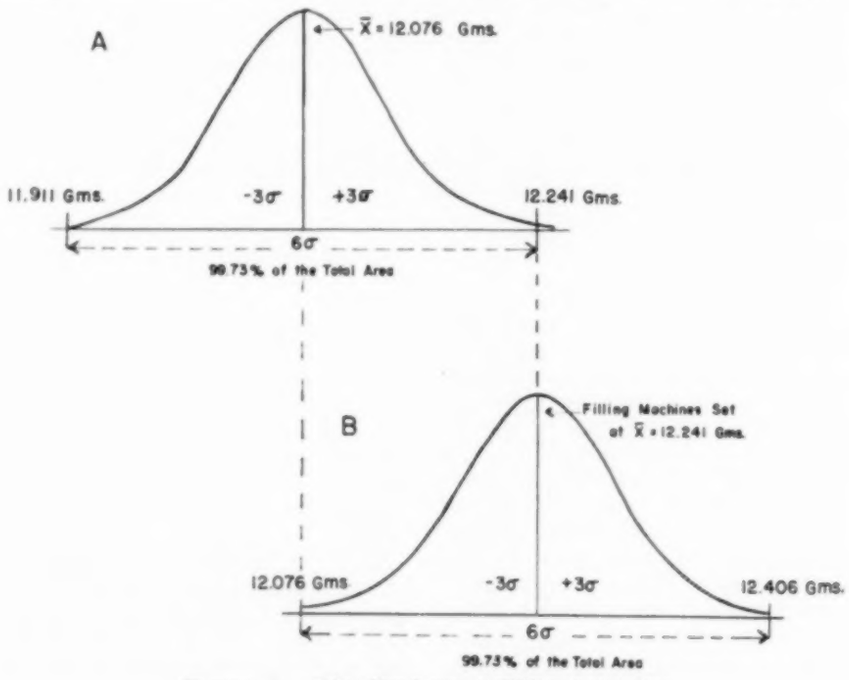

Figure 1 - **Distributions of Filling Weights**

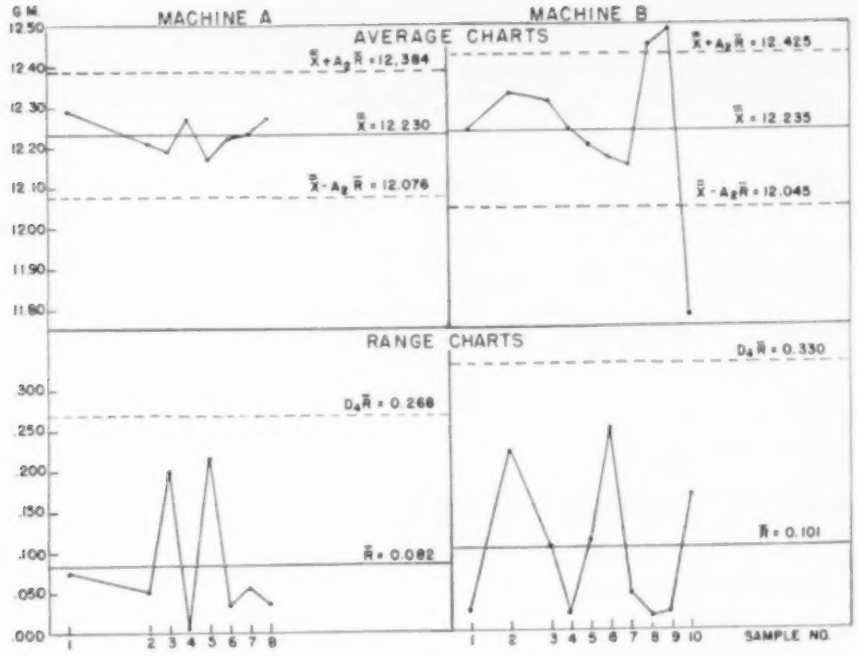

Figure 2 - **Control Charts on Performance of Two Filling Machines**

lem has now led to the establishment of a realistic specification for the operation as it now stands even though an overfill of more than 20% does not appear to be too economical. The fact remains, however, that this is about all that can be done unless a major change is made to reduce the magnitude of some of the contributing variables. The next step is to follow the performance of the filling machines with control charts. Such charts will reveal, first of all, whether the specifications arrived at will be met continually and secondly, they will be of use in maintaining this specification as well as providing clues that may result in establishing and maintaining a more economical specification.

Figure 2 shows a control chart on the performance of two machines in filling a batch of the material following the establishment of the specification. In operating a control chart, small samples are taken periodically from the production flow and the average and range measurements are computed. In this case, two samples were removed and weighed approximately every twenty minutes. The average fill was calculated as was the range (largest weight minus smallest weight) for each sample and the values plotted as shown. The reason for using the range as a measure of dispersion instead of the standard deviation is that the range of a small sample is a sufficiently efficient statistic for this purpose and is easier for production people to comprehend. In fact a good estimate of the standard deviation can be made by dividing the average range ($\bar{R}$) by a factor (d_2) which varies with sample size.*

The next step is to calculate the average of the sample averages ($\bar{\bar{X}}$) and the average range ($\bar{R}$). Control limits are then computed according to the formulae appearing in Figure 2.

It can be seen that Machine A is filling vials within the predicted limits. At first glance it would appear that Machine A was capable of doing much better since the averages were well within the control limits. The relatively wide spread in the range chart, however, is responsible for these wide limits since they are calculated from the formula $\bar{\bar{X}} \pm A_2\bar{R}$ and the averages can be expected to vary over the entire width of these control bands by chance cause alone.

Machine B shows an even larger dispersion in the range chart as well as points outside of the control limits on the average chart. These points which exceed the control limits are not due to chance and their causes must be investigated.

Assuming that the causes for the misbehavior in Machine B can be found and eliminated, there remains the problem of reducing the dispersion in both range charts. This would allow for the establishment of narrower control limtis on the average chart, thus making it possible to reduce the overfill and still maintain the same degree of assurance of meeting the specifications. At this point the other technology of the industry is called upon. It is not the purpose of this paper to discuss process management, because that would involve the discussion of a whole host of engineering specialties.

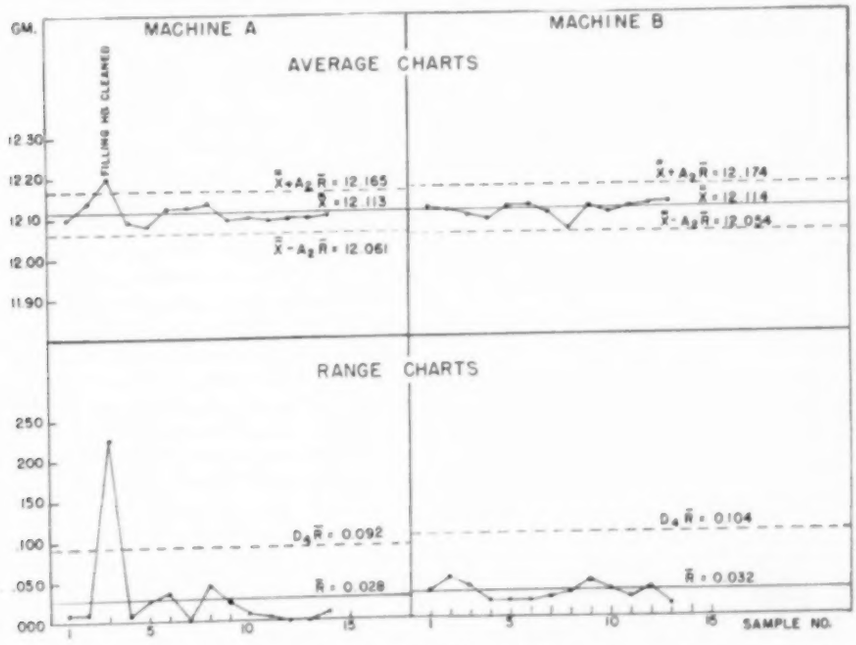

Figure 3 - **Performance of Filling Machines After Process Improvements**

*The factors A_2, D_4, d_2, etc. may be obtained for different sample sizes from a table which appears in the A. S. T. M. Manual on Presentation of Data including Supplements A and B published by the American Society for Testing Materials, 206 S. Broad St., Philadelphia, Pa.

For the problem at hand, however, it can be pointed out that nothing can be done about syringe holdup as their manufacture is not under our control. Something might be done about vial holdup and certainly a good deal of effort should be spent in an effort to reduce the variability of the filling machines. That this can be accomplished is attested to by the control chart shown in Figure 3, which represents a production batch of some months later. One need only to compare the two charts and one will have no difficulty in concluding that more vials are forthcoming from the batch produced at the later date and further, that the filled vials are much more homogeneous in their contents.

CONCLUSION

It is planned to discuss several other applications of statistical analysis in the pharmaceutical industry in subsequent issues of this journal. The field of application can cover the use of a whole host of individual tools: tests of significance, analysis of variance, sequential methods, design of experiments, single and double sampling methods, simple correlation, multiple correlation, to mention but a few. The most pertinent to the subject matter of this introductory paper, however, is the control chart method which has been briefly described.

Problems Department

G. RUPERT GAUSE, Editor

Problems for solution, and correspondence concerning material published in this department, should be addressed to

MR. G. RUPERT GAUSE
Bell Telephone Laboratories
463 West Street
New York 14, N. Y.

Submitted by:

PROFESSOR NILES H. BARNARD
The University of Nebraska

In analyzing the results of bacteria counts made on milk samples, control charts are sometimes kept in accordance with standard procedures except that logarithms of the bacteria counts are used instead of the original counts. The resulting chart may indicate a state of control whereas if the original measurements are used the resulting chart would indicate a bad lack of control. Under what conditions is it proper or desirable to convert measured values to logarithms before applying standard control chart procedures?

Solution by:

DEPARTMENT EDITOR

The object of a control chart is to determine whether measurements, obtained as a series of samples, fluctuate in a random fashion, all of the fluctuations being due to chance; or in a non-random fashion, thereby indicating the presence of assignable causes. If the fluctuations are random, it means that some basic underlying distribution exists such that any individual measurement is essentially a random drawing from this basic distribution. The underlying distribution need not necessarily be the familiar "Normal distribution." In fact the exact shape of the distribution will depend entirely upon the scale of measurement. For example, if one were interested in running control charts on the "size" of ball bearings, one might decide to measure the "size" either in terms of diameter or in terms of weight. Now since the weight of a sphere is proportional to the cube of its diameter, it would be impossible for both of these measures of "size" to be exactly a Normal distribution. If the diameter measurements are distributed Normally, the weight measurements would not be, and vice versa.

Or again, take a simple electrical circuit containing a battery of a fixed voltage and a resistance. Now suppose that random variations are introduced into the resistance such that the actual resistance is Normally distributed. In such a case, measurements of current would not be Normally distributed since the current would be proportional to the reciprocal of the resistance.

Thus it is clear that the shape of the distribution depends upon the particular scale of measurement being used and a state of statistical control does not require that the measurements be distributed Normally.

The standard procedure for control charts calls for symmetric limits for $\overline{X}$ of $\overline{\overline{X}} \pm 3\sigma/\sqrt{n}$. The use of these limits is based on the fact that for *most* distributions actually encountered in control chart work, such limits will include "practically all" of the sample averages if the measurements are random samples from some one of the more common distributions. This is largely due to the fact that averages tend to be Normally distributed even though the individual values are obviously non-Normal. For example, if the underlying distribution is triangular or even rectangular in shape, the distribution of averages of samples of size 4 or more is so close to Normal that one can hardly tell the difference by eye. Even in the case of skewed distributions, averages of samples of size 4 or more tend to be distributed symmetrically and approximately Normally. Because of this, standard control chart procedures can be applied to most measurements even though the scale of measurement is not such as to make the underlying distribution Normal. However, there are certain measurements which, because of the underlying physical and chemical principles involved, yield distributions which are so far from being Normal that special procedures such as the use of logarithms is necessary.

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As indicated in the ASTM Manual on Presentation of Data (Page 14, Note 1) the distribution of some quality characteristics is such that a transformation using logarithms of the observed values gives a substantially Normal distribution. When this is true, the use of logarithms is distinctly advantageous in control chart work. This is often the case with measurements involving biological growth such as bacteria count. Here a slight variation in temperature will tend to double or triple the effect of a slight variation in original contamination, rather than to add a fixed number of bacteria, independent of the original contamination. *Wherever simultaneous variations in the several factors which determine the measured values tend to combine their effects as products rather than as independent additive effects, the logarithms of the measured values tend to be distributed Normally.*

Where the logarithms of measured values are distributed Normally, the distribution of original values is skewed with no values less than zero and with a long tail in the positive direction. If the standard deviation of the logarithms is large, the skewness of the original measurements is very great and a large proportion of sample averages will be above the customary upper control limit $\overline{\overline{X}} + 3\sigma/\sqrt{n}$. On the other hand, if the measurements are converted to logarithms the resulting chart will indicate a state of control so long as the successive measurements behave as random drawings from the underlying distribution.

Sometimes a logarithmic scale of measurement is purposely selected by the scientist or design engineer so as to obtain measured values which are easily handled and physically meaningful. This tends to result in the measured values being distributed approximately Normally and removes the necessity for the quality control engineer applying any transformation to the scale of measurement. For example, in the communications field, volume response, amplitude gain, transmission loss, etc. are measured in terms of decibels which is the logarithm of a current ratio or voltage ratio, etc. Such measurements are frequently used in control chart work, standard procedures being applied to the results as obtained in decibels.

As indicated above, it is proper and desirable to convert measured values to logarithms in control chart work whenever the underlying distribution is more nearly Normal (or symmetric) with respect to the logarithms than with respect to the original measurements. Fortunately, the scale of measurement established by the scientist or design engineer is usually such that a transformation is not necessary. Where the need does exist, the fact is preferably established through fairly lengthy engineering experience with the quality characteristic in question or quality characteristics of a similar nature. If no background experience is available, a review of the data after 100 or more observations are obtained should indicate whether the use of logarithms would

be desirable. Frequency histograms of these data can be plotted using both the arithmetic scale and the logarithmic scale to see if the use of logarithms effects any pronounced reduction in skewness. A comparison of minimum, median, and maximum values in a group of data may sometimes indicate the need for further investigation as to the desirability of using logarithms. If the measurements themselves are distributed Normally, the difference between median and minimum should of course be approximately equal to the difference between maximum and median. However, if the logarithms are distributed Normally, the differences in logarithms should be approximately equal, which means that the ratio of the median to minimum should be approximately equal to the ratio of the maximum to the median. A comparison of these numbers can be made mentally and will usually indicate any outstanding need for the use of logarithms. However, it must be kept in mind that such relationships hold only when a state of control already exists. A careful examination of the data should always be made to assure that any pronounced skewness in original measurements is not actually due to assignable causes. In such a review, a consideration of the engineering principles involved is perhaps as important as statistical tests and considerations.

Quality Control in Six Minutes

A. G. KLOCK
Quality Control Superintendent

C. W. CARTER
Quality Control Engineer

Bigelow-Sanford Carpet Company, Inc.

IN successfully applying the modern concepts of quality control to any process, the biggest hurdle is the normal, inborn instinct of human beings to resist something which is not thoroughly understood. The most effective way in which this may be overcome is the gaining of confidence and understanding through as simple an explanation as possible.

There are two basic ingredients of a "simple" explanation. First, people may be led into the proper channels of thought by the use of personalized illustrations. Talking in terms everybody knows and understands will always arouse interest, and the simpler the illustration the better. Second, the use of visual aids, or "gadgets", should be employed. Once a person has seen such a gadget work, the picture is fairly firmly impressed. Then, as practical applications are suggested, the logic is more likely to be apparent. Furthermore, the time required for a thorough explanation may be cut to a small fraction and a high level of interest maintained throughout by letting the gadget tell its own story.

These two ingredients have been combined very successfully at the Bigelow-Sanford Carpet Company in painlessly administering the fundamental principles of Statistical Quality Control. Frequency distributions, the control chart, theory of sampling, etc., etc., are all presented in one package in the short space of six minutes.

The Bigelow-Sanford Quality Control Board, shown in Figure 1, provides the visual aid. It consists of a carriage mounted in a portable frame, with beads strung on twelve wires in the carriage. In the position shown, it resembles a Chinese Abacus, but it can also be made to represent a control chart. Using cardboard scales in brackets at the left-hand side of the board, the opportunities for applying personalized illustrations are limitless. These include such characteristics as the simple plus-and-minus scale (shown in Figure 1), shoe sizes, golf scores, I.Q., personal income (everyone understands this!), and, for our particular case, the characteristic of carpet thickness.

The board in this position illustrates the construction of a simple graph. It takes very little time to explain that consecutive measurements of any characteristic put on a chart illustrate the principle of *variation* (i.e., "A" makes $3,000 a year while "B" makes $15,000, etc.). By using homey illustrations, it is easy to show that variation applies to practically everything.

The general reaction at this point is one of "sure, but where do we go from here?" The answer is that we must recognize the two types of variation: normal and non-normal. For example, a golfer who shoots "in the seventies" happens to card an 81—or even an 85—and thinks very little of it. (He probably would call it an "off day" and let it go at that.) If that same golfer should come back with a card of 145, there undoubtedly would be some logical and specific explanation; perhaps he was playing with a broken arm—or even blindfolded. That is the distinction between normal and non-normal variation. That is what "control limits" are for on a control chart.

Let a process make a product without any external factors influencing it and the resultant production will probably be "normal" with respect to the amount of variation in any characteristic.

Again your listener asks, "Fine; how does it tie into the chart?" The answer is that the data on the chart must be analyzed further; a frequency distribution must be made. Turning the board to the vertical position, as shown in Figure 2, will allow the beads to slide to the bottom, thus forming the "Normal Distribution Curve".

Why is this called "normal"? Because it comes to a peak in the middle (average) and because it is sym-

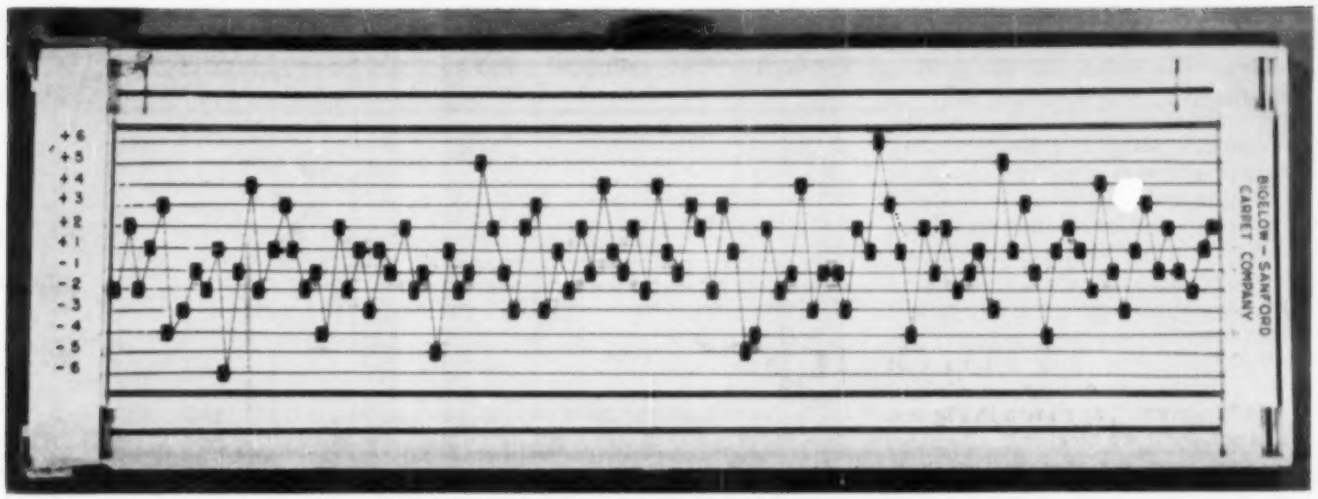

Figure 1—**The Bigelow-Sanford Quality Control Board**

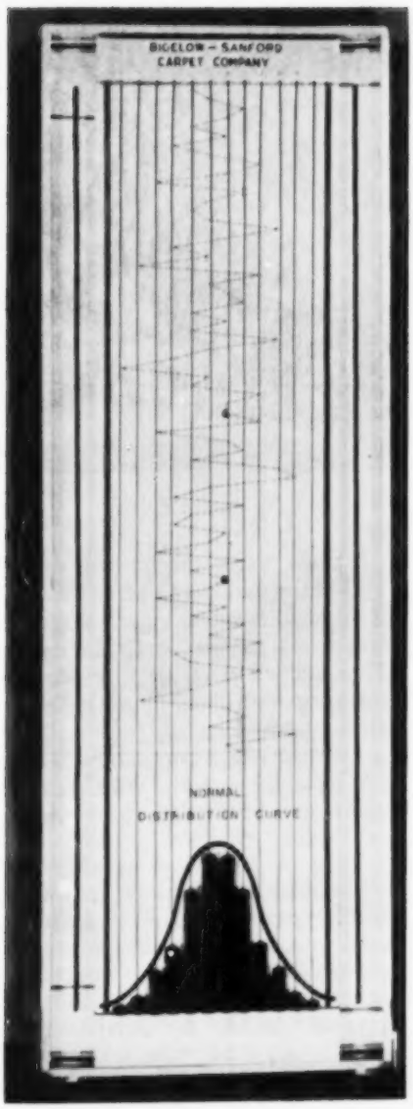

Figure 2

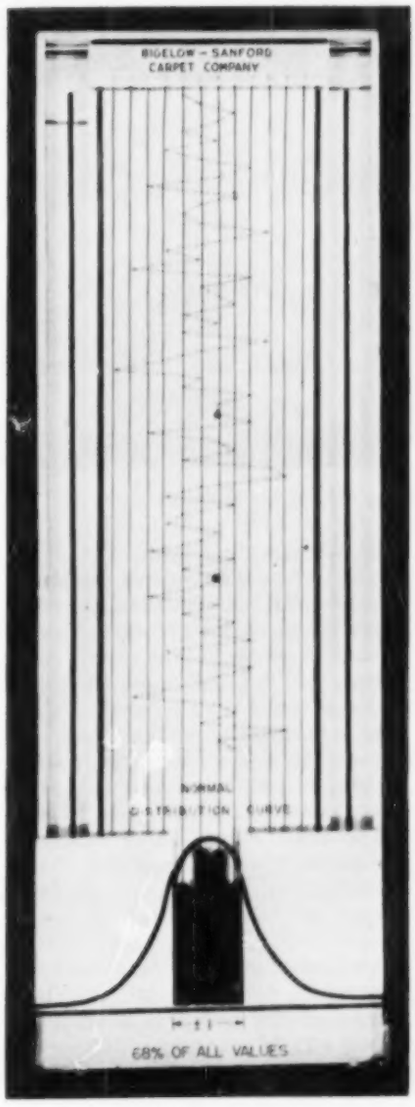

Figure 3

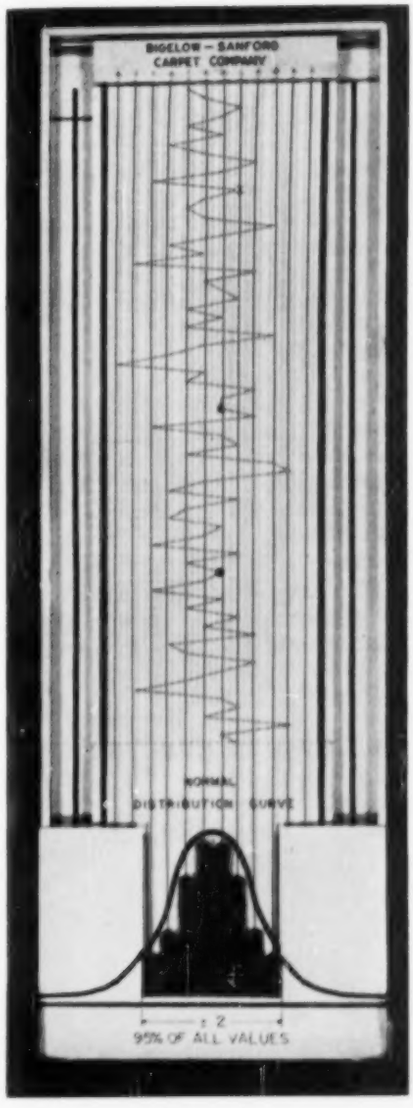

Figure 4

metrical about the average.* Any "snapshot" of a process which looks otherwise is a clue that the process is operating with a broken arm—or even blindfolded. Furthermore, the manner in which it differs from the normal curve is often the tip-off as to where and what to check. In short, the frequency distribution technique is a potent trouble-shooting weapon.

"So far, so good. But can this help me run my machine? If so, how?" It is here that we must call upon the mathematicians. They tell us that the normal curve may be divided into "segments", as shown in Figures 3, 4 and 5. If we block out all values further from the average than plus or minus one "segment", we will have, within these limits, approximately 68 percent of all the values. Similarly, plus or minus two "segments" embraces 95 percent of all values, and plus or minus three "segments" includes 99.7 percent, or all but three out of a thousand. If a production man had limits which would tell him whether his process was running "out of control" with such accuracy, could he control his process more accurately? Figure 6 shows what happens when a process average shifts over one segment. No longer are 68 percent of the values visible.

Using this sort of presentation as the basis for control charts, it is easy to sell any individual on their value in process control.

The construction of the board is simple. The frame is 18" x 60", and houses a center panel which rides on iron guides at each end. It is kept parallel by a system of wires and pulleys similar to a draftsman's straight edge.

On the panel are twelve wires representing class intervals. The wires have 100 beads on them distributed in the following order:

Wire No.	Number of Beads
1	1
2	2
3	5
4	8
5	15
6	19
7	19
8	15
9	8
10	5
11	2
12	1

*Of course, not every curve that has these two properties is necessarily "normal," but we are here purposely trying to make a very brief and non-technical presentation.

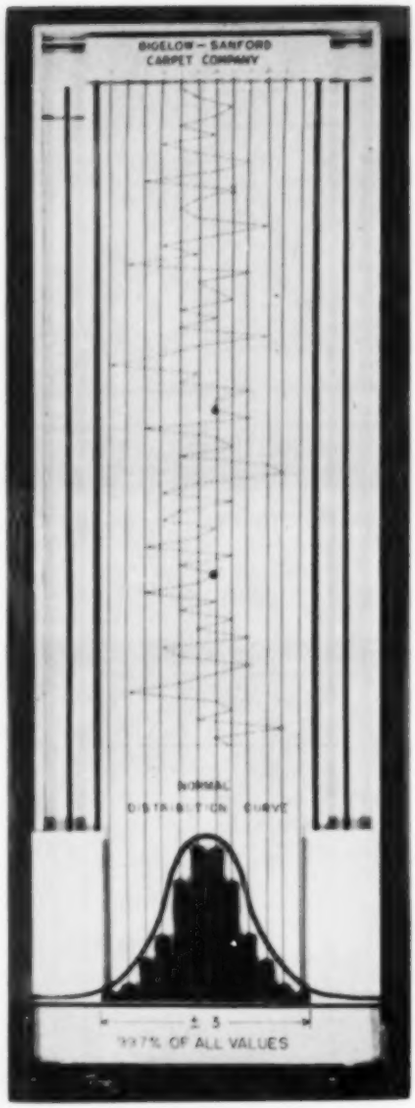

Figure 5

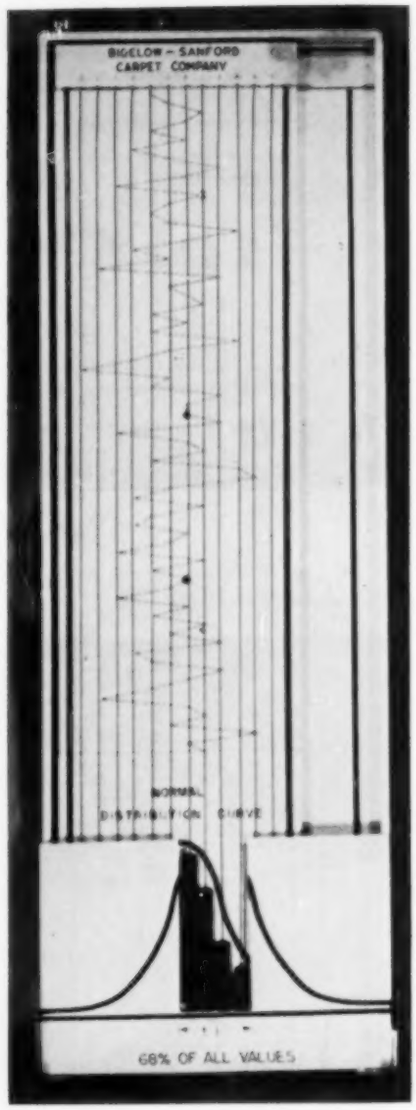

Figure 6

The wires are spaced one inch apart. On the outside of these wires are ¼-inch metal rods which represent 3-sigma control limits. The rods also add support to the panel. On the panel behind the wires is a piece of cardboard with points representing a control chart. The center panel measures 14" x 58". The panel is made so that it can move two inches, or one standard deviation, to either side. On the inside back of the case are lines made by dark blue ¼-inch cellophane tape. These lines represent the four standard deviations. At the base of the board are metallic brackets that hold scales and templates for the demonstration. On the back of the board is a spring pin lock which snaps into the panel to lock it in the middle.

In the center of the back is a female part of a "Daisy" can opener; the male part is mounted on the wall of the Quality Control Office. It is thus allowed to pivot from the horizontal to the vertical position. This enables us to use it for demonstrations and gives Quality Control atmosphere. The cost of this board is approximately ten dollars ($10.00) for material, (beads, wire, lumber) and eight hours work of a carpenter.

Thus, for a nominal outlay and the willingness to improvise, the task of installing a program of statistical quality control may be considerably lightened. Further, the effectiveness of such a program is greatly increased because the personnel who are directly concerning with running it have a basic understanding of the principles and an appreciation of its aims.

Bibliography

JOSEPH MOVSHIN, Editor

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APPLICATION—AUTOMOTIVE INDUSTRY

QUALITY CONTROL LOWERS COSTS, BOOSTS PRODUCTION, Nelson G. Meagly, Manager, Statistical Quality Control, Willys-Overland Motors, Inc.
(Iron Age, v. 165, n. 17, April 27, 1950, p. 31)

Many statistical quality control techniques are used at Willys-Overland. Their purpose is to provide factual information for corrective action. Psychological value of QC at first noted. The problem is also one of organization. Examples of techniques used are given.

APPLICATION—CHEMICAL INDUSTRY

A CASE STUDY OF HOW STATISTICAL QUALITY CONTROL EXPEDITES CHEMICAL OPERATIONS, G. N. Cornell, A. E. Staley Manufacturing Co., Decatur, Illinois
(Chemical Industries, v. 64, n. 4, April 1949, p. 568)

Examples are given of the application of several statistical methods (p chart, correlation, etc.) to problems and variables in a chemical processing plant. Examples of variables noted for control are:

a) Temperature
b) pH's
c) Moisture content
d) Color
e) % Oil content
f) % Protein

STATISTICAL PROCEDURES IN CHEMICAL INVESTIGATIONS, W. L. Gore (E. I. du-Pont de Nemours)
(Industrial & Engineering Chemistry, v. 42, n. 2, Feb. 1950, p. 320)

Two examples are presented of typical problems encountered in industrial research and pilot plant development where the statistical approach has shed new light on the factors involved in the process. Randomizing of data from various factors by the Latin Square method and others is described.

MECHANICAL PROPERTIES OF HIGH POLYMERS AS FUNCTIONS OF THE SHAPE OF THE DISTRIBUTION CURVE, Philip C. Scherer & Rembert D. McNeer, Virginia Polytechnic Institute
(Rayon & Synthetic Textiles, v. XXXI, n. 2, Feb. 1950, p. 53)

The prediction of mechanical properties of plastic films from the distribution curves of the degree of polymerization.

APPLICATION—METALLURGICAL INDUSTRY

HOW TO CONTROL POWDER PART SIZE, E. E. Ensign, Manufacturing Research, and I. A. DeGrote, Quality Analysis, Automotive Manufacturing Operations, Ford Motor Co., Dearborn, Michigan
(Iron Age, v. 165, n. 16, April 20, 1950, p. 83)

A well organized article, tracing step-by-step, the analysis of the dimensions of a powdered metal bushing as it was brought under control with the aid of statistical methods. Illustrated with several charts and photographs.

HOW GE BUYS POWDER PARTS, J. D. Carey, Metallurgical Engineer and A. G. Pison, Quality Control Engineer, General Electric Co., Bridgeport, Conn.
(Iron Age, v. 165, n. 16, April 20, 1950, p. 95)

Describes initial tests on sintered iron parts to determine physical properties. After first samples are approved, statistical sampling, control charts and certificates of quality are used to insure continuation of quality standards. Illustrated with photographs and a chart.

APPLICATION—METAL WORKING

HOW TO MAKE CONSISTENT SPOT WELDS, J. Heuschkel & H. Bitzer, Research Laboratories, Westinghouse Electric Corp.
(Steel, v. 126, n. 6, Feb. 1950, p. 82)

This is a general discussion on spot welding as such, but does contain some examples of the application of statistical methods.

QUALITY CONTROL OF FLASHWELDING, Gilbert C. Close
(Modern Machine Shop, June 1950, p. 80)

A description of the control procedure for strength of flash-welded parts as used at Northrop Aircraft. Statistical methods are not noted in this description.

"LOOK MA—NO HANDS!", Clifford W. Kennedy
(Modern Machine Shop, v. 23, n. 1, June 1950, p. 194)

The author describes an application in a Screw Machine Department in which all of the inspection is done by the operators. A sample of two is taken and control limits are based on specification allowances rather than on process limits.

APPLICATION—MISCELLANEOUS

QUALITY CONTROL IN THE RAYON PLANT, W. B. Sears, Werner Textile Consultants, New York
(Rayon & Synthetic Textile, v. XXX, n. 10, Oct. 1949, p. 57)

Mr. Sears presents an outline of the application of Statistical Quality Control to the rayon plant. Examples of reports used are given. The importance of adequate and accurate reporting of data is stressed. Only through such data can management take proper action quickly on the specific points needing correction.

ENGINEERING & EXPERIMENTS

NEW CONTROL SYSTEM IMPROVES PIPE QUALITY, D. A. EVANS, National Tube Co., Pittsburgh, Pa.
(Iron Age, v. 165, n. 15, April 13, 1950, p. 82)

Multiple correlation is used to control the variables influencing the properties of line pipe steel. Manganese, carbon, and thickness are related to elongation and ultimate strength through this statistical technique. Charts used to present the relationship.

PRACTICAL ENGINEERING USES OF PROBABILITY PAPER—PART 1, A. Boyajian, G. E. Company, Pittsfield, Mass.
(General Electric Review, v. 53, n. 6, June 1950, p. 15)

The analysis of variable data by "probability paper" methods can provide much interesting information for relatively little effort in calculation. Several examples of the use of probability paper to analyze distributions are given.

MANAGEMENT & PERSONNEL

BOOSTING QUALITY WITH PLANT CAMPAIGNS
(Modern Industry, v. 19, n. 2, Feb. 1950, p. 47)

An Editorial article based on practice at Monsanto Chemical Co., Plastics Division—Springfield, Mass. Photographs showing use of poster, scoreboards, etc., to advertise quality within the plant. Quality control helps keep down costs and customers satisfied. The approach to supervisors and operators for quality consciousness is stressed.

ORGANIZING A QUALITY CONTROL PROGRAM, K. W. Kingsland, Kingsland & Associates, Toronto, Canada
(Modern Management, v. IX, n. 8, November 1949, p. 8)

An approach to the installation of a quality control program and department by top management. Problems and considerations involved are noted.

INDUSTRY'S TOOL IN COMPETITIVE MARKETS, P. C. Clarke, Assistant General Manager, Hunter Spring Co.
(Dun's Review, April 1949, p. 13)

Quality control and statistical techniques are used to improve and maintain quality without excessive costs. Quality control used with production, engineering, sales, etc., as well as for inspection. Examples of use given.

A frequency distribution of product is sent to customer as a help to both user and manufacturer.

THE QUALITY CONTROL DEPARTMENT AS A TRAINING GROUND FOR FUTURE SUPERVISORY PERSONNEL, E. H. Robinson, Director of Quality Control, Johnson & Johnson, Chicago, Ill.
(Tool & Die Journal, v. XVI, n. 2, May 1950, p. 49)

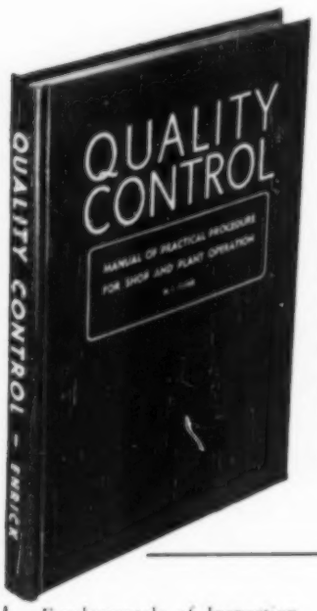
This was originally presented in a panel discussion at the 3rd Annual ASQC Convention. The Quality Control Department is related in its activities to many other plant functions. Excellent training and background for future supervisory personnel are obtained through this relationship. Also published in IQC, January 1950.

STATISTICS CAN CHANGE A JOB CLASSIFICATION, William A. MacCrehan, Jr., Professor, New York University College of Engineering
(Tool Engineer, v. XXIV, n. 6, June 1950, p. 35)

Professor MacCrehan discusses the organization and problems of the inspection department with particular emphasis on the use of statistical methods to help solve some of these problems.

REGAINING QUALITY REQUIRES DEFINITE PLAN, E. M. Findley, Jr., Management Consultant, East Chester, N. Y.
(Textile World, v. 99, n. 5, May 1949, p. 103)

The importance of quality control as a money saver for industry is noted and compared to its low cost (3-5% of total quality loss). Quality control is also presented as an aid in obtaining workers' interest and cooperation for quality.



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SAMPLING PLANS & RELATED TOPICS

INSPECTING INCOMING GOODS, M. T. Shelhimer, Douglas Aircraft Company (Mill & Factory, v. XLVI, n. 3, March 1950, p. 119)

Receiving inspection problems have been so reduced in this aircraft plant that thousands of dollars are being saved annually through elimination of assembly delays. A standard of acceptance previously impossible to obtain has been established. The cooperation between various plant divisions is responsible for achieving such results.

THEORY & APPLICATION—GENERAL

DEVELOPING CHARTS FOR QUALITY CONTROL WORK, R. S. Saddoris, Director of Quality, A. O. Smith Corp. (SAE Journal, v. 58, n. 4, April 1950, p. 25)

This is an excerpt from a paper "Quality Control and Inspection" presented before the Milwaukee section of the SAE.

An elementary article showing development of tally sheet from ungrouped data. Then further development is made into bar and scatter diagrams and control charts.

GRAPHICAL STATISTICAL METHODS, W. A. Hinton (Wireless Engineer, v. 26, n. 315, Dec. 1949, p. 400)

An introduction to graphical methods for statistical problems. Largely a description of uses for probability paper, with attention to goodness of fit. Illustrated.

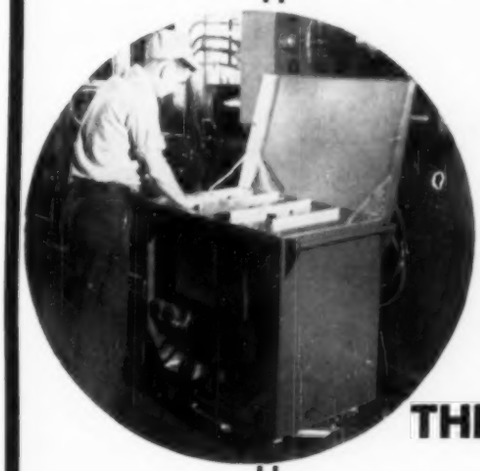
GRAPHICAL STATISTICS—AN ENGINEERING APPROACH—II, L. R. Hill & P. L. Schmidt (Westinghouse Engineer, v. 10, n. 3, May 1950)

Method of drawing confidence envelopes and of finding significant differences using probability paper. Illustrated with graphs. Part I in v. 10, n. 2, March 1950.

QUALITY CONTROL PROGRAM PROVES VALUE THROUGH WASTE REDUCTION AT M-H (Plastics Industry, v. 8, n. 3, March 1950)

This article presents a general introductory type discussion of quality control by statistical methods. Several techniques such as the $\overline{X}$ & R chart, tolerance determination, and sampling are described. Results of the quality control program at Minneapolis-Honeywell and illustrations of the dollar savings that resulted are given.

Quality Control in Molded Plastics Depends on Temperature Control IN THE MOLD . . . possible with THERMOLATOR



A Thermolator, attached to an injection molding press, controls mold temperature within the close limits necessary for defect-free casting.

More Data On THERMOLATOR

Interesting Booklet on "THERMOLATOR CONTROL" — yours for the asking. WRITE . . .

Thermolator controls the temperature of each half of a plastics mold independently of the other, by means of high velocity circulation of water whose temperature is automatically controlled, by draining or adding heat. Thermolator will control temperatures within 2° F. with dependability and accuracy, where molds are properly designed with water lines.

If You Seek Quality—Seek the Molder Who Uses "Thermolator Control"

INDUSTRIAL MANUFACTURING CORP.
31 E. GEORGIA STREET • INDIANAPOLIS 4, INDIANA

REPRESENTATIVES: F. W. Jennison, Room 603, 570 7th Ave., New York 13, N. Y.
Pacific Scientific Co., 1430 Grande Vista Ave., Los Angeles 23, Calif.
Richardson Agencies Limited, 454 King St. West, Toronto 1, Canada.

FIFTH ANNUAL CONVENTION OF ASQC, MAY 23-24, 1951

Cleveland Public Auditorium — Convention Headquarters: Cleveland Hotel

Watch for program details in subsequent issues.

Practical Aids

ELLIS R. OTT, Editor

Interference Risk When Normal Distributions Overlap

R. W. HANNA, Chief Inspector, and R. C. VARNUM, Mathematician

Barber-Colman Company, Rockford, Illinois

The proper establishment of dimensional limits in the manufacture of a product is a major factor in the control of costs of the component parts. If tolerance specifications of the components can be increased *without impairing the ultimate quality*, great savings can sometimes be effected. In this article we offer a method by which individual component tolerances can be increased in many instances to actually improve the quality of assembly fits, provided the production of the component parts is statistically controlled. (The controlled process is a means of approximating a normal distribution of sizes between specified limits.)

Sometimes the tolerances are closer than the manufacturing process can hold. At other times they are wider than economy of manufacture requires. In either case a review of the problem will indicate which of the following procedures is economically desirable: (1) correct the process, (2) adjust the specification limits, or (3) continue to accept the loss in the rejected assemblies. We are concerned here with the second of these choices; in particular, with the problem of finding the risks involved when distributions of mating parts are widened so as to overlap.

It is common practice for many engineers to specify dimensions for mating parts which differ appreciably so that there is essentially no chance of interference, i.e., little chance of getting pairs which will not assemble. However this method of avoiding interference can result in the equally disturbing problem of extreme looseness of fit.

Send your "Practical Aid" contribution to:
Dr. Ellis R. Ott
Rutgers University
77 Hamilton Street
New Brunswick, N. J.

Consider, too, what happens sometimes when mating parts are delivered to the assembly floor with greatly overlapping distributions. Under general inspection procedures in many plants both types would be subjected to a 100% screening and the pieces found in the overlapping regions would be removed for correction or scrapping. In this way the assembly floor is assured of good mating parts but at an unnecessarily high cost in inspection, rework, and scrap.

The purpose of this paper is to determine the probability of interference. This risk of interference is much less than is popularly expected, and, in many cases, is small enough to be economically acceptable. The underlying theory can be found in standard texts* so need not be repeated here. By means of a series of curves and two division operations, the answer can be found without direct reference to the additive character of variances or the area under the normal curve.

Since an experiment is frequently more convincing than a theoretical proof, we made two normal distributions of 998 integers each. One distribution had a mean of 60 and a standard deviation of 10. The other distribution had a mean of 30 and a standard deviation of 10. (See the upper sketch at the right of Figure 1.) Each author made 998 drawings until his distribution was exhausted, recording the integers in the order of drawing. The results were then compared and it was found that 981 pairs were free of interference, that is, the number from the first distribution was larger than its mate from the second distribution. The interference risk was thus found experimentally to be 17 out of 998, or 1.7%.

The chips were not replaced after each drawing because the distributions were designed to represent two batches of n o r m a l l y distributed manufactured parts delivered for assembly. The two distributions selected for this experiment could also represent parts delivered from two production lines for continuous assembly when considered over an adequate length of time. The normalcy of the distribution of parts from a production line will be improved by a mixed accumulation of parts prior to assembly.

To find from our chart the predicted interference risk of the two distributions described above we divide 10 by 10 to obtain 1, then we subtract 30 from 60 to obtain 30. This value is divided by 10 to give a value of 3. By looking for 1 on the lower scale and 3 on the vertical scale we note that our answer lies between the 1% and 2% curves, and that 1.7% is a reasonable estimate. (See the upper sketch.)

The example in the lower sketch assumes that one distribution has three times the spread of the other and that the distance between their means is six times the standard de-

*E. L. Grant: *Statistical Quality Control* McGraw Hill Book Co. (1949) pp. 326-332

PROBABILITY OF INTERFERENCE OF TWO OVERLAPPING NORMAL FREQUENCY DISTRIBUTIONS

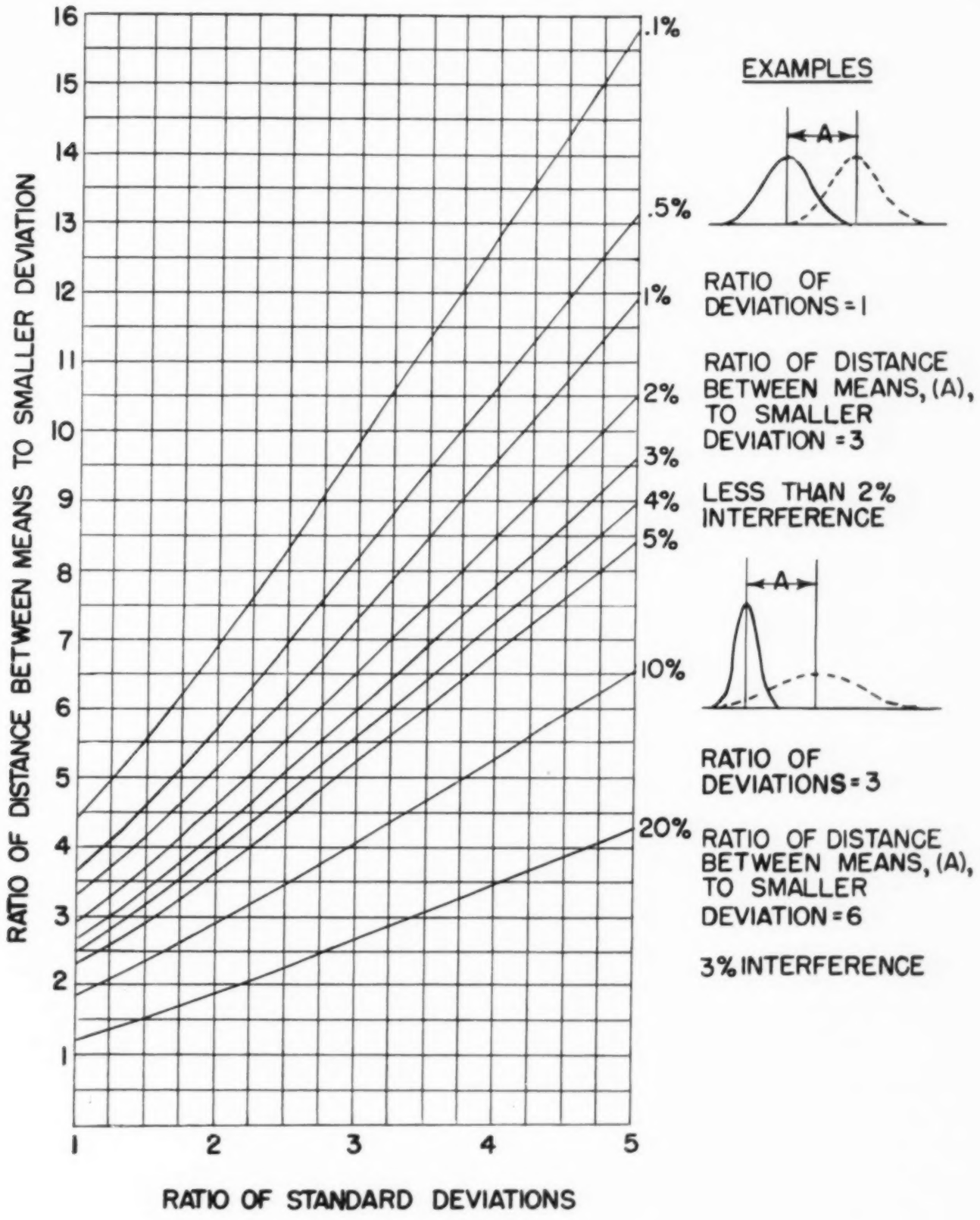


Figure 1

viation of the tighter distribution. Using the customary assumption that the spread is six standard deviations, this example has placed the lower limit of each distribution at the same point as shown, so that the tight distribution actually lies within the wider one. In spite of this, the interference risk is only 3% which is found from the chart by locating 3 on the lower scale, 6 on the vertical scale, and observing that these lines cross on the 3% curve.

For any two distributions of mating parts the interference risk is found as follows: (1) divide the larger standard deviation by the smaller; (2) locate this value on the lower scale; (3) subtract the means, or averages; (4) divide this difference by the smaller standard deviation; (5) locate the result of the division in (4) on the vertical scale; (6) find the point which is above the lower scale value and to the right of the vertical scale value; (7) determine the interference risk from the percent curves passing nearest this point.

By a study of these examples and a little practice in using the chart, a person can quickly determine the interference risk involved in proposed limits and thereby lessen the prevalent fear of overlapping.

Let it be emphasized, however, that these results are based on *normal* distributions and *random* selection of pairs. Experiments are now being conducted by the authors on certain non-normal distributions to discover what compensations may be necessary in this procedure for such cases.

ANNUAL REPORTS

At the Annual Meeting of the Society in Milwaukee on 1 June 1950, the President, the Executive Secretary, and the Treasurer presented annual reports on behalf of the Board of Directors. These reports were duly accepted. They have been extended to include the balance of the fiscal year, in accordance with the provisions of Sections 29. c. (3), 29. d. (5), and 33. h. of the Constitution and are published below.

REPORT OF THE BOARD OF DIRECTORS

The Board of Directors of the American Society for Quality Control, Incorporated, presents herewith to the membership its fourth Annual Report, covering the fiscal year from 1 July 1949 to 30 June 1950. This report summarizes the principal activities of the Society during the year, more detailed information having been reported in Industrial Quality Control in the course of the year.

Appended to this report are the Annual Reports of the Executive Secretary and of the Treasurer. The Executive Secretary's Report sets forth the status of the membership roll and the roll of Sections; the Treasurer's Report states the financial condition of the Society as of the close of the fiscal year. The Auditing Committee's certification of the Treasurer's Report is also appended.

Board of Directors Meeting

Only one meeting of the Board was held during the year—in Milwaukee on 3 June 1950 following the Convention. All of the Officers and 22 of the Directors were present. Important action taken at this meeting included:

1. Confirmation of the action of the Executive Committee in recognizing the following as Sections of the Society:

Toledo	Greater Muskegon
Columbus	San Francisco Bay Area
Denver	Rhode Island
Erie	

2. Approval of the action of the Executive Committee in establishing new technical committees as follows:

   Chemical Technical Committee
   Electronics Technical Committee
   Automotive Technical Committee
   Aircraft Technical Committee

3. Establishment of the policy of handling future Society Conventions as national conventions under the sponsorship and financing of the American Society.
4. Acceptance of reports from Chairmen of Society Committees, covering the activities and program of each of these committees.

Executive Committee Meetings

Four meetings of the Executive Committee were held during the year as follows:

New York—October 2-3, 1949
Princeton—December 3-4, 1949
New York—February 18-19, 1950
Milwaukee—May 31 and June 2, 1950

These meetings were devoted to general discussion of Society activities and plans. Their proceedings have largely been reported in the succeeding issues of Industrial Quality Control.

In addition to these formal meetings, the Officers have been in frequent consultation and discussion with other members of the Executive Committee on important Society affairs.

Sections Visited by President Wareham

During the past year, your President has visited and taken part in meetings of six of the Sections of the Society:

Washington	Metropolitan
Southern Tier	Philadelphia
Western Massachusetts	Delaware

In addition, he addressed the National Convention of th Society in Milwaukee.

Annual Meeting 1949-50

The Annual Meeting of the Society was held in Milwaukee on 1 June 1950. The proceedings of the Annual Meeting are recorded in some detail in the American Society News section of this issue of Industrial Quality Control. Officers elected for the fiscal year 1950-51 were as follows:

President: Wade R. Weaver
Vice President: Martin A. Brumbaugh
Executive Secretary: Simon Collier
Treasurer: Alfred L. Davis

National Convention

The Fourth Convention of the Society was held in Milwaukee on June 1 and 2, 1950, in conjunction with the Fifth Midwest Quality Control Conference. The proceedings of the Convention were reported in the July 1950 issue of Industrial Quality Control. Outstanding success of the Convention was largely due to the teamwork of the twelve Midwest Sections and to the hard work of the Convention Committees which played host to the Society.

Regional Meetings

Two large Regional Meetings were held during the year: Midwest—St. Louis, Missouri, November 10-11, 1949; Middle Atlantic—Princeton, New Jersey, December 2-3, 1949. Each of these meetings was sponsored by all of the American Society Sections in the Region. In addition to luncheon and dinner sessions of a more general character, clinical sessions were devoted to specific applications of quality control

techniques. Both meetings were highly successful.

Section Meetings

All of the Society's Sections held well-attended meetings regularly during the year. Technical sessions were frequently preceded by a less formal dinner session. A number of Sections conducted highly successful quality control training courses just preceding the regular technical meetings.

Section meetings constitute a substantial and important contribution to the life of the Society and to the benefit of individual members. These meetings have increased in scope and strength with the continued growth of the national society.

Sections

Last year, the Board reported 35 Sections active in the Society. During this year, seven new Sections have been added, so that the Society now has 42 active Sections.

Membership

As a result of teamwork throughout the Society, there has been a substantial increase in Society membership during the year. At the end of the year, Society corporate membership was more than 3500 as compared with 2620 at the beginning of the year—an increase of more than 33%.

Industrial Quality Control

The Editorial Board, under the able chairmanship of Professor Mason E. Wescott, has increased the magazine in scope and in usefulness during the year. A number of valuable departments have been added and regularly appear in each issue. The outstanding success of the 116-page Convention Issue is a landmark in Society affairs. Improvements in technical content and in general make-up of the magazine have increased its usefulness to members and to libraries and other institutions.

The Industrial Quality Control News Supplement, under the able editorship of Ernest H. Robinson, has appeared throughout the year in those months when there is no issue of the magazine. A valuable feature of the Supplement has been the bi-monthly tabulation of future Section meetings.

Advertising

With the enlarged circulation of Industrial Quality Control, now well in excess of 3800, the Board of Directors is convinced that the magazine possesses real appeal to commercial advertisers and that such advertising should provide an important source of income for the Society.

During the past year, the work of Mr. Raymond S. Saddoris as Chairman of the Advertising Committee has laid important ground-work for increased advertising in future years. Mr. Saddoris is working closely with the National Directors of each Section in steps to further develop magazine advertising.

Work of Society Committees

The increasing activity of Society Committees has stimulated the work of the Society in many areas. Each Standing, Technical, Special, or General Committee has carried on important work which has assisted the Officers in carrying through Society program. Recommendations of these committees, together with action taken, have been reported in previous issues of Industrial Quality Control.

The Society extends a vote of thanks to each member who has served on our Committees for his service in making the national program of maximum value to members.

Awards

At the Annual Convention in Milwaukee, the Shewhart Medal was presented to Mr. Harold F. Dodge of New York, N. Y., in recognition of his outstanding contributions in the field of modern quality control.

Also at the Convention, the first Brumbaugh Award was presented to Mr. Leonard A. Seder of Boston, Massachusetts, in recognition of his excellent paper on "The Technique of Experimenting in the Factory" as published in the March 1948 issue of Industrial Quality Control.

Sustaining Contributions

The Society received a gift of $500 from the New England Sections from the proceeds of the Third National Convention held in Boston on May 5 and 6, 1949. A similar gift of $500 was made by the Midwest Sections from the proceeds of the Fourth Midwest Quality Control Conference, held in St. Louis, Missouri, on November 10 and 11, 1949.

Society Membership Badges

During the year, your President worked with representatives of the L. G. Balfour Company in designing membership badges for Members, Senior Members, and Fellows. The design of each of these badges was carefully considered by the Executive Committee and the badges were adopted officially for the Society. Each badge follows the pattern of Society insignia but has a distinctive identification.

Appreciation

The Board of Directors expresses its deep appreciation to all ASQC Committees and Committee Chairman, to Section Officers, and to the members in general for the loyal and effective efforts which all have devoted to the advancement of the Society and its aims.

For the Board of Directors,
RALPH E. WAREHAM, President

Chappaqua, New York, June 30, 1950

REPORT OF THE EXECUTIVE SECRETARY FOR THE YEAR ENDING JUNE 30, 1950

At the end of the Society's first fiscal year on June 30, 1947, there were 25 active Sections of the Society and a total membership of 1926. How this has grown until the present time is illustrated in the following table:

Date	*Membership*	*Active Sections*
June 30, 1947	1926	25
June 30, 1948	2102	31
June 30, 1949	2638	35
June 30, 1950	3510	42

In addition, we have 305 institutional subscriptions to INDUSTRIAL QUALITY CONTROL, making our total mailing list for the magazine 3815.

Seven new Sections were recognized during the year. They are as follows: Toledo, Columbus, Denver, Erie, Greater Muskegon, San Francisco Bay Area, and Rhode Island. The last two were recognized by the Executive Committee at its meeting of May 31, 1950, so did not enroll any national members directly during the 1949-50 year. The Rhode Island Section had previously been a subsection of the Boston Section. Groups are working on organizing Sections in Mexico City, Mexico; Montreal, Canada; Seattle, Washington; Louisville, Kentucky; Frankfort, Kentucky; Evansville, Indiana; Parkersburg, West Virginia; Akron, Ohio; and Albuquerque, New Mexico.

The membership of the Society as of June 30, 1950 was composed as follows:

	New Members	*Renewing*	*Total*
Fellows		81	81
Senior Members	298	957	1255
Members	1152	979	2131
Total	1450	2017	3467
Members-in-Training	39	4	43
Total	1489	2021	3510

Exhibit A shows the membership of the Society as of June 30, 1950 by grade, Region, and Section. It is to be noted that 89% of the 1948-49 Senior members renewed their memberships in 1949-50, as compared with 65% of the Member grade members.

EXHIBIT A—American Society for Quality Control, Inc.—Membership Report as of June 30, 1950

Region and Section	Membership June 30, 1949	Membership, June 30, 1950			
		Fellows	Senior Members	Members	Total
New England Region					
Boston	134	5	51	79	135
Hartford	41	1	17	41	59
New Hampshire			1	22	23
Southern Connecticut	51	1	17	32	50
Western Massachusetts	48	1	26	24	51
TOTAL	274	8	112	198	318
Middle Atlantic Region					
Baltimore	39	1	6	40	47
Delaware	33	4	10	20	34
Metropolitan	184	17	109	101	227
Philadelphia	97	3	74	119	196
Washington	32	1	7	35	43
TOTAL	385	26	206	315	547
Northern Region					
Buffalo	76	1	19	50	70
*Michigan	112	1	49	111	161
Mid-Hudson	25		12	30	42
*Muskegon			6	5	11
Rochester	76	1	55	29	85
Southern Tier	57		16	37	53
Syracuse	112	4	33	68	105
Toronto	25	1	6	27	34
TOTAL	483	8	196	357	561
Central Region					
Cincinnati	13		9	21	30
Columbus			3	10	13
Dayton	63		25	61	86
Erie		1	4	19	24
Georgia	32	2	19	16	37
Ohio	246	4	68	141	213
Pittsburgh	80	1	29	47	77
Tennessee	45		22	39	61
Toledo			1	75	76
TOTAL	479	8	180	429	617
Mid-West Region					
Chicago	170	7	119	94	220
Denver			4	24	28
Illinois	20	2	15	5	22
Indianapolis	132	3	86	186	275
Iowa	101	6	59	37	102
Milwaukee	100	1	65	63	129
Minnesota	30	1	16	13	30
Muncie			10	19	29
N. E. Indiana	81	1	21	48	70
Rock River Valley	14		24	28	52
St. Louis	90	3	46	69	118
South Texas	19	1	1	38	40
TOTAL	757	25	466	624	1115
Western Region					
California	55	1	19	33	53
TOTAL	55	1	19	33	53
Members-at-large	188	5	76	175	256
Members-in-training	18				43
GRAND TOTALS	2639	81	1255	2131	3510

*In response to their petition the Executive Committee has authorized the transfer of the Michigan and Greater Muskegon Sections to the Central Region, effective July 1, 1950.

It will also be noted from Exhibit A that the Society now has 33% more members than it had on June 30, 1949. On that date we had 25% more members than on June 30, 1948, showing that the Society grew at a faster rate during the 1949-50 year. This growth is very encouraging and is a tribute to the hard work put in by the Sections, as well as to a growing awareness by industry of the value of statistical quality control methods.

We have on several occasions acted as an employment clearing house between members of the Society and industry.

The manual covering relationships between the Sections and the office of the Executive Secretary, which was issued to the Section officers in July 1949, has proved a great help in the administration of the Society. We are now revising this manual so that it will reflect recent amendments to the Society constitution and so that it will include changes that have been indicated as necessary on the basis of experience during the past year. Other changes are the result of suggestions made by Section officers, members of the Board of Directors, and the Special Committee on National Offices. It is hoped to have the revised manual ready for distribution early in August.

During the past year plans were worked out for the sale of reprints of the article on statistical quality control in the December 1949 issue of FORTUNE magazine and of copies of the National Industrial Conference Board report entitled "Quality Control Methods and Company Plans." Our entire allotment of this report has been sold to members of the Society.

The Executive Committee approved the design of membership pins, and a plan has been set up for their sale to members.

The single-sheet application blank adopted last year has proved a great success, in that it costs less to print, is more convenient to handle by all concerned, and requires less filing space. At the same time it enables the applicant to supply substantially as much information as did the old two-sheet blank.

Our office this past year has seen continued improvement in the carrying out of its functions with all of the Sections of the Society. This has been possible only because of the cooperation that we have obtained from them. In addition, thanks are due to Mr. P. B. Proctor, Quality Control Engineer at Johns-Manville, and Mr. J. S. Herz, my staff assistant, because of their unstinting help in putting in many hours of their own time on the work of this office.

Respectfully submitted,

SIMON COLLIER,

July 17, 1950 Executive Secretary

REPORT OF TREASURER

Appended hereto are Balance Sheet of the Society as of June 30, 1950 (Exhibit B), and Statement of Cash Receipts and Disbursements of the Society for the fiscal year July 1, 1949 through June 30, 1950, inclusive (Exhibit C).

Respectfully submitted,

ALFRED L. DAVIS, Treasurer

July 15, 1950 Rochester, New York

EXHIBIT B

AMERICAN SOCIETY FOR QUALITY CONTROL, INCORPORATED

Balance Sheet—June 30, 1950

Assets			
Cash:			
Current funds:			
On hand for deposit	$1,238.04		
Demand deposit	4,465.55		
Time deposit	2,687.08	$8,390.67	
Special funds—time deposits:			
Shewhart Medal Fund	$ 171.25		
Brumbaugh Award Fund	965.07	1,136.32	$9,526.99
Accounts receivable:			
Sale of back issues of publications and reprints		$ 211.75	
Sale of technical literature and conference papers		124.06	
Library subscriptions		34.50	370.31
Inventories—at nominal amounts:			
Back issues of publications, reprints and conference papers		$ 1.00	
Stationery and supplies		1.00	2.00
			$9,899.30
Liabilities and Surplus			
Accounts payable:			
Executive Secretary—for reimbursement of petty disbursements		$ 48.51	
For Society pins		243.17	$ 291.6
Deferred income:			
Membership dues paid in advance		$ 46.00	
Estimated unearned portion of library subscriptions		942.50	988.50
Reserves:			
For Shewhart Medal Fund		$ 171.25	
For Brumbaugh Award Fund		965.07	1,136.32
Surplus			7,482.80
			$9,899.30

EXHIBIT C

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS

AMERICAN SOCIETY FOR QUALITY CONTROL, INCORPORATED

Year ended June 30, 1950

CURRENT FUNDS

Receipts:			
Membership dues:			
Members in training	$ 96.00		
Regular members	8,103.00		
Senior members	9,621.50		
Fellows	908.00		
Overpayments	49.00	$18,777.50	
Less refunds of overpayments		91.00	$18,686.50
Sustaining contributions:			
Third New England Conference		$ 500.00	
Fourth Midwest Conference		500.00	1,000.00
Publications:			
Advertising (exclusive of advertising in May 1950 convention issue)		$ 2,321.50	
Proceeds from May 1950 convention issue sponsored by Fifth Midwest Conference		1,146.39	
Library subscriptions		1,860.00	
Sales of back issues		1,289.10	6,616.99
Sales of Conference Papers and other technical literature		$ 1,389.84	
Less printing and other costs		1,238.47	151.37
Sales of Society pins		$ 393.00	
Less partial payments made for cost of pins sold		43.88	349.12
Sales of emblem cuts and miscellaneous			15.35
Interest received on bank deposit			20.44
TOTAL RECEIPTS			$26,839.77
Disbursements:			
Publications:			
Publishing—magazine (exclusive of cost of May 1950 convention issue)		$ 7,035.78	
Publishing—news supplement		867.45	
Reprinting—back issues		531.30	
Mailing supplies and expense		828.30	
Postage		1,166.54	
Office supplies and expense		183.67	
Secretarial services		1,158.40	
Advertising commissions and cash discounts allowed		312.19	
Traveling expense		325.52	
Miscellaneous		47.41	12,456.56
Committees and Sections:			
Printing costs—public relations material, reprints, stationery, etc.		$ 298.12	
Postage		13.56	
Miscellaneous supplies and expense		47.87	
		$ 359.55	
Less reimbursements received from Sections		176.48	183.07
President:			
Postage		$ 100.68	
Office supplies and expense		275.06	
Traveling expense		159.45	535.19

Executive Secretary:		
Secretarial salaries	$ 4,617.40	
Printing and mimeographing	703.75	
1948-1949 Yearbook	911.76	
Postage	493.81	
Office supplies and expense	1,351.41	
Office rent	780.00	
Traveling expense	36.00	$ 8,894.13
Treasurer:		
Secretarial salaries	$ 1,458.60	
Office supplies and expense	65.77	
Bond premium	25.00	
Bank collection and exchange fees	29.39	
Traveling expense	174.14	
Accounting service	195.00	1,947.90
TOTAL DISBURSEMENTS		$24,016.85
CASH RECEIPTS IN EXCESS OF CASH DISBURSEMENTS		$ 2,822.92
Cash on hand and on deposit at June 30, 1949		5,567.75
Cash on hand and on deposit at June 30, 1950		$ 8,390.67

SPECIAL FUNDS

Shewhart Medal Fund:	
Receipts:	
Interest received on bank deposit	$ 2.01
Disbursements:	
Cost of striking 1950 Medal	32.33
CASH DISBURSEMENTS IN EXCESS OF CASH RECEIPTS	$ 30.32
Cash on deposit at June 30, 1949	201.57
Cash on deposit at June 30, 1950	$ 171.25
Brumbaugh Award Fund:	
Receipts:	
Interest received on bank deposit	$ 10.07
Disbursements:	
Cash award to Leonard A. Seder (May 26, 1950)	50.00
CASH DISBURSEMENTS IN EXCESS OF CASH RECEIPTS	$ 39.93
Cash on deposit at June 30, 1949	1,005.00
Cash on deposit at June 30, 1950	$ 965.07

REPORT OF AUDITING COMMITTEE

With the approval of the Executive Committee, we retained Ernst & Ernst, Certified Public Accountants, to audit the books of the American Society for Quality Control, Inc. Relying on this audit and the certificate of Ernst & Ernst, we are of the opinion that the accompanying Balance Sheet and Statement of Receipts and Disbursements fairly present the financial position of the Society as of June 30, 1950, and its recorded cash transactions for the fiscal year ending that date.

Auditing Committee
HOWARD L. BOLTON
G. RUPERT GAUSE
PAUL A. ROBERT
JOSEPH SADOWSKI
July 15, 1950 HOWARD L. JONES, Chairman

CERTIFICATE OF AUDIT

American Society for Quality Control, Incorporated

We have examined the balance sheet of American Society for Quality Control, Incorporated as of June 30, 1950 and the statement of cash receipts and disbursements for the year then ended and, without making a detailed audit of the transactions, have examined or tested accounting records maintained by the Treasurer of the Society, and other supporting evidence as hereinafter outlined.

Cash on hand was counted and cash on deposit at June 30, 1950 was reconciled with amounts reported to us by Lincoln Rochester Trust Company. We traced the recorded cash receipts for the fiscal year to deposits shown by bank statements, inspected reports made by the Executive Secretary for a period of six months selected by us in support of amounts recorded as having been received for membership dues and tested other data on file supporting other recorded cash receipts. We also inspected canceled bank checks, invoices, and other data in support of the recorded disbursements for the year.

We examined data and checked computations supporting amounts shown in the balance sheet for accounts receivable, accounts payable, and deferred income at June 30, 1950.

In our opinion, based upon our examination as outlined above, the accompanying balance sheet and statement of cash receipts and disbursements present fairly the position of American Society for Quality Control, Incorporated at June 30, 1950 and the recorded cash transactions of the Society for the year then ended.

ERNST & ERNST

July 10, 1950, Rochester, New York

REPORT OF THE EXAMINING COMMITTEE

Your Examining Committee continued to be quite active during the 1949-50 fiscal year. During this period all applications for transfer to the Grade of Fellow and all names of members of ASQC under consideration because of a suggestion by members of the Examining Committee or by other members of ASQC were reviewed four times. As a result, 44 members of ASQC were recommended, or invited to submit an application, for transfer to the Grade of Fellow. Of these 44 recommendations or invitations, 11 transfers were effected as of June 30, 1950. The Committee hopes that each of the other 33 members will submit an application very promptly.

Prior to July 1, 1949, 91 members of ASQC were either recommended, or invited to submit an application, for transfer to the Grade of Fellow. Of this number, 81 applications have been received and approved while 10 members have not accepted the invitation.

As of June 30, 1950, therefore, 135 members of ASQC have been recommended, or invited to submit an application, for transfer to the Grade of Fellow. Of this number the following 92 names have the Grade of Fellow:

Philip L. Alger
Stanley C. Amren
A. Griffin Ashcroft
James M. Ballowe
Claudius S. Barrett
Stephan C. Bates
Henry J. Becker
Oliver P. Beckwith
*Arthur Bender, Jr.
Charles A. Bicking
Martin A. Brumbaugh
Archie R. Burgess
Irving W. Burr
Philip C. Clarke
Paul C. Clifford

Alonzo C. Cohen, Jr.
Simon Collier
Richard Coolbaugh
*Allen T. Craig
Cecil C. Craig
Arthur G. Dalton
Besse B. Day
W. Edwards Deming
Harold F. Dodge
Howard C. Dunkle
George D. Edwards
Ernest L. Fay
Enock B. Ferrell
Elwood E. Folsom, Jr.
Harold A. Freeman

Eugene L. Grant
Frank E. Grubbs
Frederick J. Halton, Jr.
Ralph A. Hefner
John A. Henry
Irwin S. Hoffer
Carl E. Hoover
Charles J. Hudson
*Robert S. Inglis
*Archie R. Jackson
Warren E. Jones
Joseph M. Juran
Lester S. Kauffman
Clifford W. Kennedy
*Halsey H. Kent
Lloyd A. Knowler

E. Vernon Lewis
*Wyatt H. Lewis
Bernard H. Lloyd
E. H. MacNiece
*Charles L. Matz
Edward C. Molina
Morton M. Newcomb
Carl E. Noble
Roland H. Noel
Edwin G. Olds
Paul S. Olmstead
Ellis R. Ott
Guy G. Parkin
Ellsworth G. D. Paterson
Andrew I. Peterson

Kort K. Pfabe
Phillip B. Proctor
Warren R. Purcell
Edward A. Reynolds
A. C. Richmond
Paul R. Rider
E. H. Robinson
Harry G. Romig
Keith E. Ross
*Raymond S. Saddoris
Edward M. Schrock
Charles R. Scott, Jr.
*Leonard A. Seder
Dorian Shainin
Walter A. Shewhart

Leslie E. Simon
Bonnie B. Small
Jerome H. Steen
*James V. Strela
John V. Sturtevant
Albert W. Swan
*Julian H. Toulouse
Frederick Trowbridge
J. Frederick Verigan
Clifford A. Wallace
Ralph E. Wareham
Wade R. Weaver
Grant Wernimont
Mason E. Wescott
Albert E. R. Westman
Samuel S. Wilks

*Grade of Fellow during 1949-50 fiscal year.

The Examining Committee makes the following recommendations* to the Executive Committee and to the Board of Directors of ASQC:

1. That the Executive Secretary continue to acknowledge each application for transfer to the Grade of Fellow and transmit it promptly to the Chairman of the Examining Committee who is to advise the Executive Secretary of its receipt;
2. That the Examining Committee continue the policy of having invitations issued to members to submit applications for transfer to the Grade of Fellow;
3. That the Executive Secretary continue to accept applications for transfer to the Grade of Fellow;
4. That the Examining Committee continue to review all applications for transfer to the Grade of Fellow at least two times per fiscal year, one of which is to be in committee meeting if at all possible;
5. That the Examining Committee continue to hold all applications not recommended for transfer to the Grade of Fellow in open file;
6. That the Examining Committee be authorized to secure information directly from a member under consideration to aid in its decision;
7. That the Grade of Fellow be regarded as having been attained only after receipt of an official communication to that effect by the Executive Secretary or the President of ASQC; and
8. That a complete list of Fellows be printed and distributed to the membership each year with an appropriate marking for members transferred to the Grade of Fellow since the last published list. It is suggested that such list be printed in the Yearbook whenever published or in Industrial Quality Control.

The Examining Committee makes the following suggestions* to the Executive Committee and to the Board of Directors of ASQC:

1. That a member of the Examining Committee, who has served at least one year, be ineligible to succeed himself immediately; and
2. That the Grade of Fellow not be regarded as honorary but that it should be regarded an honor to attain it.

The members of your Examining Committee wish to thank the Officers, particularly Mr. Ralph E. Wareham, President, and Mr. Simon Collier, Executive Secretary, the members of the Executive Committee, and the Board of Directors for their most excellent cooperation and support during the past year. Also thanks are due the many members of ASQC who gave so graciously of their time in gathering information concerning names under consideration and in submitting data concerning names for future consideration.

Respectfully submitted,
MARTIN A. BRUMBAUGH
CHARLES J. HUDSON
EDWIN G. OLDS
PAUL S. OLMSTEAD
June 30, 1950 LLOYD A. KNOWLER, Chairman

*The recommendations and suggestions were adopted in Milwaukee, June 1-2, 1950.

NOTICE

Membership lapel badges are now available as follows:

Grade of Membership	Badge	Price
Member	Sterling Silver	$1.75
Senior Member	10 K Gold	$3.75
Fellow	10 K Gold with Sapphire	$4.75
Honorary Member	10 K Gold with Diamond	.....

All the above prices include Federal Excise Taxes. Badges may be purchased *only* through local Section Secretaries except for Members-at-Large who may order badges through the Executive Secretary.

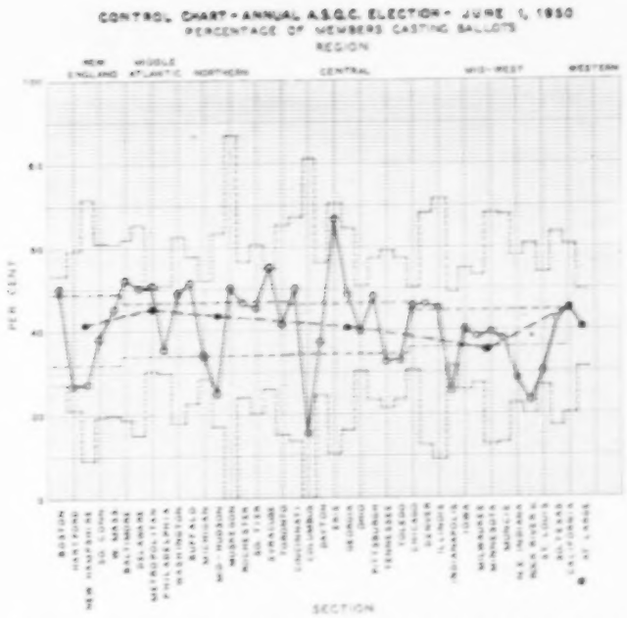
STOCK LIST
ASQC Publications

Publication	Price	Quantity
INDUSTRIAL QUALITY CONTROL		
Volumes I, II, III, IV, V, VI (July 1944—May 1950)	$8.00 per Volume including Index	Unlimited
Individual Issues	$1.50 per copy	Unlimited
Library Subscriptions (Current)	$6.00 per year	
CONVENTION PROCEEDINGS		
"Conference Papers" of the First Annual Convention (29 Papers) Bound Volume	$3.50 per copy	20
"Abstracts of Papers" Third Annual Convention (41 Papers) Bound Volume	$1.50 per copy	123
"Convention Papers" Fourth Annual Convention (10 separate Papers) Unbound	$ .30 per Paper $2.50 per set of 10 Papers	1000
MISCELLANEOUS		
"Training Course Manual in Statistical Quality Control"	1 to 25 copies: $ .50 each 26 to 50 copies: $ .40 each 51 copies and up: $ .25 each	Supply Exhausted
"Statistical Quality Control." A reprint of the article in *Fortune*, December 1949	$ .10 per copy OR $4.16 per 100 plus postage	3500
"Quality Control Methods and Company Plans", National Industrial Conference Board		Supply Exhausted

Order from: American Society for Quality Control, Alfred L. Davis, Treasurer, 65 Plymouth Ave. South, Rochester 8, N. Y.

SUPPLEMENTARY TELLERS REPORT
1950 Returns

The keen interest of the members in this election and in the Amendments proposed for adoption is evidenced by the fact that 40.1% of the members returned ballots. Only a few expressed displeasure with the ballot because of the listing of only one candidate for each office. These individuals should operate under Section 55 of the Constitution and



nominate other candidates by petition (securing the names of 25 members on each petition for a candidate) so that they might vote for the men they wish to sponsor. This year and in subsequent years they can write in other candidates, if they so desire. A small number, less than 1%, wrote in names of candidates, and they were recorded in the tally. Some members expressed a desire to have a copy of the Sections of the Constitution for which Amendments were proposed and also the proposed Amendments in detail in order to vote intelligently. We believe this should be given them in the future.

In preceding years a control chart covering the percentage of members casting ballots has been prepared and presented as a cover page for Industrial Quality Control. This year a similar chart drawn by Miss Elizabeth F. Lockey has been prepared and accompanies this Supplementary Report. A new feature has been added—the inclusion of the performance of each region with 3σ limit lines for such points. In 1950, of the 41 Sections, one, Indianapolis, was significantly low, its value being 70/275 or 25.5%; two were significantly high. Syracuse returned 58/105 or 55.2% and Metropolitan returned 114/224 or 50.9% of their ballots. For the Regions, the Midwest Region was significantly low, returning 391/1113 or 35.13% of its ballots. No definite reasons for these out-of-limit points are known. However, at the May meeting of the Metropolitan Section, Dr. P. S. Olmstead appealed to the members present to send in their ballots, particularly for the Proposed Amendments and this additional pressure may have pushed the Metropolitan Section above its upper 3σ limit.

H. G. ROMIG, Chairman
Tellers Committee

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QUALITY CONTROL COURSE FOR THE CHEMICAL INDUSTRIES

An eight-day intensive training course in *Quality Control for the Chemical Industries* will be offered by the Rochester Institute of Technology at Rochester, N. Y., October 10-18, 1950. The content of this sixth annual training program in statistical methods and techniques is devoted exclusively to the control problems of the chemical and allied process industries. The course is designed for those responsible for controlling quality of product either in the analytical laboratory or directly in the manufacturing process.

The tuition of $100.00 per person includes books and supplies. Room accommodations will be available at the Hotel Rochester. Further inquiries should be addressed to the course coordinator, Alfred L. Davis, Rochester Institute of Technology, Rochester 8, New York.

AMERICAN SOCIETY NEWS

MARCH OF PROGRESS—IQC

Primary efforts to turn out a special convention issue were an outstanding success and resulted in a definite milestone in the progress of Industrial Quality Control. The magazine was conceived under the leadership of Martin Brumbaugh, newly elected Vice-President of the Society, and the first issue, published in July, 1944, was of 16 pages. Upon the formation of the National Society in February, 1946, the entire magazine was turned over to the Society by the Federated Societies and under the continued leadership of Martin Brumbaugh, and since July, 1947, that of Mason Wescott, it has grown progressively to 32 pages as a standard issue.

For the Convention Issue of 116 pages our Editorial Staff had a tremendous amount of assistance from numerous members of the Mid-West Planning Committee. In addition to its success as a periodical issue this special issue was a financial success and it is thought that members may be interested in a brief accounting.

Total Income from Advertising and Other Sources	$6,114.43
Total Publication and Distribution Expense	4,968.04
Gross Income	$1,146.39

The Society would have been under financial obligation to publish a normal May issue the cost of which has been calculated as follows:

Net Separable Publishing Cost	$1,052.19
Total Distribution Costs	212.79
Total Expense	$1,264.98
Normal Advertising Income	301.55
Normal Financial Obligation	$ 963.43

Due to the aggressive ideas of the Mid-West groups, the personal efforts of the various individuals involved, plus the pride of execution of a notable achievement, the financial position of the Society was improved as follows:

Gross Income from Convention Issue	$1,146.39
Normal Expense for Normal May Issue	963.43
Net Realization	$2,109.82

To this capital gain has been added a portion of the "anticipated" increase in income resulting from the new dues structure and the basic size of the magazine has been increased for the ensuing year to 40 pages minimum. This increases the budget for the publications activities about 35%.

The Society is indebted to the Mid-West Planning Committee for its outstanding aid in making this new landmark possible.

ANNUAL MEETING—1950

The Fourth Annual Meeting of the Society was held in the Milwaukee Auditorium, Milwaukee, on Thursday, June 1, 1950.

President Wareham called the meeting to order at 4:10 p.m. and appointed:

Messrs. Carl V. Garrett, Indiana Section

Henry J. Jacobson, Chicago Section

Charles R. Kendel, Ohio Section

Philip B. Proctor, Metropolitan Section

Harry G. Romig, Metropolitan Section, Chairman

to act as the Committee of Tellers for the election of Officers for the coming year and for vote on Constitutional Amendments.

Executive Secretary Collier reported that 3433 postal ballots had been sent out to the membership and that 1376 of these had been returned to him up to the time of the meeting. The Tellers received the ballots from the Executive Secretary and retired to make their tally.

The President then presented the Board of Directors' report on the progress and accomplishments of the Society during the 1949-50 fiscal year. Reports were also presented by the Executive Secretary and the Treasurer. Upon motion duly made and seconded, all of these reports were ordered accepted as submitted; they have been extended to include the balance of the fiscal year and are printed in full in this issue of the magazine.

The Committee of Tellers then presented its report on voting on the proposed Constitutional Amendments as follows:

1. *Changes in Dues:* Sections 12, 13, 21, and 22.

	No.	Percent of Total
Disqualified due to defacement	2	
Invalid due to No Marks (Blank)	12	
Total Qualified Votes (For and Against)	1362	39.7
Total Ballots	1376	
FOR	1161	85.2
AGAINST	201	14.8
Favorable Sections	41	100.0
Unfavorable Sections	0	0

AMENDMENTS ADOPTED.

2. *Changes in Date of Suspension of Delinquent Members:*

	No.	Percent of Total
Disqualified due to defacement	2	
Invalid due to No Marks (Blank)	17	
Total Qualified Votes (For and Against)	1357	39.5
Total Ballots	1376	
FOR	1278	94.2
AGAINST	79	5.8
Favorable Sections	41	100.0
Unfavorable Sections	0	0

AMENDMENT ADOPTED.

3. *Changes in Dates for Annual Meetings:* Sections 52, 55, 56, 60.a, 60.c, and 66.

	No.	Percent of Total
Disqualified due to defacement	2	
Invalid due to No Marks (Blank)	24	
Total Qualified Votes (For and Against)	1350	39.3
Total Ballots	1376	
FOR	1318	97.6
AGAINST	32	2.4
Favorable Sections	41	100.0
Unfavorable Sections	0	0

AMENDMENTS ADOPTED.

4. *Changes to Permit Write-In Ballots:* Sections 57, 58, 59, and 60.d.

	No.	Percent of Total
Disqualified due to defacement	2	
Invalid due to No Marks (Blank)	18	
Total Qualified Votes (For and Against)	1356	39.5
Total Ballots	1376	
FOR	1304	96.2
AGAINST	52	3.8
Favorable Sections	41	100.0
Unfavorable Sections	0	0

AMENDMENTS ADOPTED.

5. *Changes to Clarify Procedures for Adoption of Constitutional Amendments:* Section 67.

	No.	Percent of Total
Disqualified due to defacement	2	
Invalid due to No Marks (Blank)	20	
Total Qualified Votes (For and Against)	1354	39.4
Total Ballots	1376	
FOR	1342	99.1
AGAINST	12	0.9
Favorable Sections	41	100.0
Unfavorable Sections	0	0

AMENDMENT ADOPTED.

The Annual Meeting was then temporarily adjourned until the close of the Society Banquet on Thursday evening, at which time the Committee of Tellers presented the following report on voting for Officers for the 1950-51 year:

Vote for President:
Wade R. Weaver 1342
All Others 12

For Vice President:
Martin A. Brumbaugh 1346
All Others 9

For Executive Secretary:
Simon Collier 1350
All Others 4

For Treasurer:
Alfred L. Davis 1348
All Others 6

The reports of the Committee of Tellers were accepted with thanks and the committee was discharged. Messrs. Weaver, Brumbaugh, Collier, and Davis were declared elected.

President Wareham then turned the gavel and the affairs of the Society to the new President, Wade R. Weaver.

PUBLICITY AND PUBLIC RELATIONS COMMITTEE

A very comprehensive report has been issued by this Committee, providing practical suggestions and aids to Section publicity programs. A copy has been sent to each Section representative on the Committee. If any group needs assistance in this direction the report offers ideas, based upon experience, which are tried and proven. All the Sections are indebted to Cliff Kennedy and his Committee. Copies may be obtained by writing to:

C. W. Kennedy
Federal Products Corp.
1144 Eddy St.
Providence, R. I.

AKRON-OHIO SUBSECTION FORMED

Assisted by five (5) members of the Ohio Section, a new group has been formed in Akron, Ohio. With an initial membership of 20 members the group will be known as the AKRON-OHIO SUBSECTION and has selected E. E. Ammon of Goodyear Aircraft as its Chairman. This unit will operate as a subsection of the Ohio Section. A hearty welcome is extended to all the new members and a vote of appreciation to our old members who contributed to the organization of the new group.

1951 CONVENTION

The 1951 National Convention will be held in Cleveland at the Cleveland Public Auditorium. Due to a conflict in dates it has been necessary to alter slightly the already announced dates and the Convention is now scheduled for May 23rd and May 24th. A program of broad interest has already been prepared. Make your plans now to go to Cleveland and assist in building TODAY'S FOUNDATION FOR TOMORROW'S REPUTATION.

COMMITTEE APPOINTMENTS

(a) Harold F. Dodge, Chairman of the Standards Committee announces the appointment of Irving W. Burr, Professor of Mathematics at Purdue, replacing S. S. Wilks who asked to be relieved of service due to the press of other business.

(b) Terms of service of members of the Brumbaugh Award Committee are four (4) years with two (2) members retiring each year. C. S. Barrett of Chicago and Parker D. Deans of Richmond, Va., are retiring this year. Chairman Halsey H. Kent announces the appointment of L. A. Seder, Gillette Safety Razor Co., Boston, and C. E. Stines, National Cash Register Co., Dayton, as the new members of this Committee.

(c) Lloyd A. Knowler, Chairman of the Examining Committee, announces the appointment for a five (5) year term beginning July 1, 1950, of Wyatt H. Lewis, General Electric Co., Ontario, California, replacing Paul S. Olmstead of Murray Hill, New Jersey, who is retiring according to rotation plan. The Society is indebted to Paul for his several years of devoted service.

(d) The recently established Automotive Technical Committee is composed of the following: Chairman, R. D. Long, International Harvester, Fort Wayne, Ind.; Vice-

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1. **Specifying the precision to be aimed at and the biases to be evaluated.**
2. **Designing the sample mathematically to achieve the desired precision at the lowest cost.**
3. **Appraising the results after the survey has been finished to see what they mean and how the next survey can be improved.**

CONTENTS: Part I—The Specification of the Reliability Required: The Planning of Surveys. The Various Errors of a Survey. Part II—Some Elementary Theory for Design: Moments and Expected Values. Some Variances in Random Sampling. Multistage Sampling. Ratio-Estimates, and Choice of Sampling Unit. Allocation in Stratified Sampling. Distinction between Enumerative and Analytic Studies. Control of Risks in Sampling. Part III—Some Theory for Analysis and Estimation of Precision: The Sample as a Basis for Action. Estimation of the Precision of a Sample. Part IV—Applications of Some of the Foregoing Theory: Inventories by Sampling. A Population Sample for Greece. Part V—Some Further Theory for Design and Analysis: Detailed Study of Some Binomial and Related Distributions. The Gamma and Beta Functions. Distribution of the Variance in Samples from a Normal Universe. Tests for Hypotheses in Normal Theory. The Distribution of External and Internal Variances.

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Chairman, S. C. Starnaman, Oldsmobile, Detroit, Michigan; Secretary, W. H. Smith, Ford Motor, Detroit, Michigan. This Committee has a sizeable job confronting it and will appreciate suggestions from all interested parties.

(e) The Executive Committee, at its June 2, 1950 meeting authorized the formation of an Aircraft Technical Committee and named Dorian Shainin, Hamilton Standard Division of United Aircraft, Hartford, Conn., as its Chairman. Mr. John G. Rutherford, Glenn L. Martin Co., Baltimore, has agreed to serve as Vice-Chairman and additional appointments will be made as the plans of this committee progress.

(f) A debt of outstanding gratitude is due Philip L. Alger of the General Electric Co., retiring Chairman of the Shewhart Medal Committee. With the assistance of many from his wide acquaintance, Mr. Alger formulated and activated the Committee, raised the necessary funds to underwrite the Medal, arranged for the designing and casting of the first medals, and guided the Committee in its selection of the first two medalists. It is with sincere appreciation for a magnificent job that the Society herewith expresses its appreciation to Mr. Alger.

Warren R. Purcell, Sylvania Electric Products, Salem, Mass., has accepted the appointment as Chairman of the Committee, replacing Mr. Alger.

Also retiring this year are Charles A. Bicking of Wilmington, Delaware and Ernest L. Fay of Moline, Illinois, according to the three-(3)-year rotation plan of the Committee. Accepting new appointments are Lloyd A. Knowler, State University of Iowa, and Brig. Gen. Leslie E. Simon, Department of the Army, Washington, D. C.

(g) As observant readers of this issue of Industrial Quality Control have noted, the Editorial Board has been expanded by the addition of the following: Eugene L. Grant, Stanford University, California, and Frank E. Grubbs, Aberdeen Proving Ground, Maryland. A rotation plan with three (3) members retiring each year, as recommended by the Editorial Board Report, will shortly be set up.

(h) Dr. Julian T. Toulouse, Owens-Illinois Glass Company, Toledo, Ohio, and Secretary-Treasurer of the Toledo Section, has been appointed General Chairman of the Committee on Relations with Other Technical Societies. Your President has served in this capacity for the last two (2) years and it is with considerable confidence that he turns over this task to Dr. Toulouse. The problems of properly formulating and administering the National policies on this very important subject are assuming considerable significance with the rapid expansion of Quality Control techniques in nearly every phase of Engineering. It is vital that the Society have farsighted policies and programs designed to strengthen the Society and its Sections in all of their technical relationships. Dr. Toulouse will welcome suggestions along the above lines.

The Society wishes to express its appreciation to those retiring Committee members for their loyal service and to welcome the new appointees.

CONSULTING SERVICES

Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society.

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IOWA BASIC SQC COURSE

A ten-day intensive training course in Quality Control by Statistical Methods will be offered by The State University of Iowa at Iowa City, October 31—November 10, 1950. This will be an introductory (not an advanced) course which will follow the same general pattern of previous introductory courses.

Instruction will be by lecture, demonstration, laboratory work, and evening question and problem discussion sessions, with the emphasis on practical interpretation throughout.

The tuition fee of $100 per person includes all necessary instructional materials. Room accommodations will be available at the Jefferson Hotel in Iowa City. Make room reservations directly with the hotel. Further inquiries concerning this course should be addressed to: Professor Lloyd A. Knowler, Chairman, Department of Mathematics, The State University of Iowa, Iowa City, Iowa.

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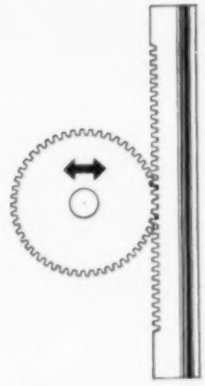

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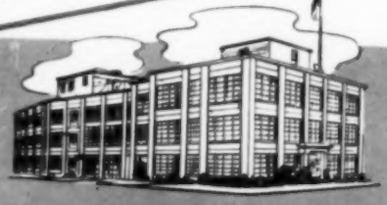

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